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A Complete Balanced Fertilizer Recommendation for Tomato grown in Sri Lanka

Saman Herath[A], **Darshani Kumaragamage[B]** and Srimathie Indraratne[C]

[A]Coconut development Board, Lunuwila, Sri Lanka. Email samanherath2@yahoo.com
[B]Environmental Studies Program, University of Winnipeg, Winnipeg, Manitoba, Canada Email d.Kumaragamage@uwinnipeg.ca
[C]Department of Soil Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka, Email srimathii@pdn.ac.lk

Abstract
An integrated approach of formulating a complete and a balanced fertilizer recommendation was tested in the field with tomato as the test crop. A representative soil sample was analyzed for available nutrient status for 11 nutrients and acidity using a three-step extraction technique. Fertilizers were recommended based on the soil nutrient status and the results of a series of fixation experiments for P, K, Cu, Mn, Fe, Zn, S and B. A greenhouse nutrient survey using a modified missing element technique confirmed the deficiencies of nutrients identified through soil analysis. Treatments that provided one nutrient at a deficient level had significantly low dry mater yields ($p<0.05$) compared to the optimum, which provided all nutrients at adequate levels. In the field, the highest tomato yields and the highest net profits were obtained with the treatment providing the highest level of N, P and K (150 % N, 75 % P and 75 % K), while providing B and S at an adjusted optimum level. Providing nutrients based on the systematic approach was beneficial in terms of tomato yield and profit.

Key Words
Fertilizer recommendation, tomato, site-specific, balanced nutrition.

Introduction
Tomato is a popular vegetable crop in Sri Lanka, which is well adapted for different climatic conditions, soil types and altitude. Though farmers use high yielding crop varieties in the country, they rarely reach the potential yield of the crop due to poor fertilizer management and inherent low fertility of Sri Lankan soils. A systematic procedure to diagnose nutrient deficiencies and other soil related problems (Hunter 1984; Portch 1998) had been effectively used to determine yield-limiting nutrients in soils from different locations in Sri Lanka (Kumaragamage and Indraratne 2002). The results revealed that most soils were deficient in N, P, K, B and S while few soils were deficient in Ca, Mg and other micronutrients (Kumaragamage and Indraratne 2002). The present fertilizer recommendation for annual short-term crops in Sri Lanka often does not include secondary nutrients and micronutrients. The main objective of this study was to investigate the potential of adapting this systematic approach to formulate a fertilizer recommendation on site-specific basis for tomato and to test this recommendation in the field.

Methods
The experimental site selected for this study was a well-drained upland field with nearly 8% slope at the University Research Farm, Dodangolla (Mid Country Intermediate Zone), Sri Lanka. The soils belong to Immature Brown Loam great soil group (Typic Eutropepts Coarse, Non Calcareous Isohyperthemic). The annual rainfall in the region was 1400 mm while the average annual temperature was 29-32^{o} C. A representative composite soil sample (0-30 cm) was analyzed for physical and chemical properties using standard methods. Available nutrient status was determined by a three step extraction method; extraction with ASI solution (0.25 *M* $NaHCO_3$+ 0.01 *M* EDTA+0.01 *M* NH_4F) for P, K, Cu, Fe, Mn and Zn, 1 *M* KCl extraction for NH_4-N, Ca, Mg and Na, and 0.08 *M* $CaH_2(H_2PO_4)_2.H_2O$ extraction for B and S (Hunter 1984; Portch 1998). A fixation study was conducted to identify the fixation capacity of the soil for P, K, Cu, Zn. Fe. Mn, S and B. The amount of fertilizer to be supplemented was calculated based on the initial nutrient values and adjusted based on the fixation capacity. An optimum fertilizer recommendation was formulated and tested in the greenhouse using a modified missing element technique using sorghum as the indicator plant. The greenhouse nutrient survey was conducted with 14 treatments, one optimum treatment and 13 individual nutrient treatments (plus or minus). All the 13 nutrient treatments were identical to the optimum with the exception of one nutrient (or lime), which is either not supplemented (a minus treatment) or supplemented (a plus treatment) based on the results of routine analysis. The nutrients, which were in

sufficient amounts were not given in the optimum treatment, but supplied to the respective nutrient treatment (a plus treatment), to examine the effect of supplying an extra amount of the nutrient on yield even though soil analysis indicated supplementing was not required. If the soil analysis indicated a deficiency, the nutrient was supplied to the optimum treatment, but not in the nutrient treatment (a minus treatment), to see the effect of not supplying the nutrient when soil analysis indicates supplementing was required.

The recommendation was tested in the field using tomato (variety *Thilina*) for four seasons. Seventeen treatments (Table 1) were tested in the field using a Randomized Complete Block design with four replicates. Tomato yield and the net profit for each treatment were determined. Analysis of variance (ANOVA) of tomato yield data was performed with mean separation by Duncan New Multiple Range Test. For all statistical analyses, significance was set at $p \leq 0.05$.

Table 1. Description of the seventeen fertility treatments tested I the field experiment

Treatment	Description	Nutrients added (kg /ha)			
		N	P	K	S
1	Low N treatment	110	160	250	50
2	**Optimum**	220	160	250	50
3	High N treatment	330	160	250	50
4	No P treatment	220	0	250	50
5	Low P treatment	220	80	250	50
6	High P treatment	220	240	250	50
7	No K treatment	220	160	0	50
8	Low K treatment	220	160	125	50
9	High K treatment	220	160	375	50
10	No S treatment	220	160	250	0
11	No B treatment	220	160	250	50
12	High PK treatment	220	240	375	50
13	High NPK treatment	330	240	375	50
14	No PK treatment	220	0	0	50
15	50% of optimum N,P, K	110	80	125	50
16	Department of Agriculture recommendation	135	40	75	0
17	Control	0	0	0	0

Results

The soil had a sandy clay loam texture with an organic matter content of 0.6%. The soil is slightly acidic in reaction with a pH of 6.3 but had no detectable active acidity. Cation exchange capacity of the tested soil was 12.7 $cmol_c\ kg^{-1}$.The amounts of available nutrients extracted using the 3-step extraction method were interpreted using the interpretive guide of Hunter and Portch (2002). The soil was extremely deficient in N, P, K, S and B and marginally deficient in Zn (Table 2). The levels of Ca, Mg, Fe and Mn were sufficient without reaching toxic levels, while the level of Cu is slightly above the toxic level (Table 2).

The soil had high fixing capacity for P, K, S and B, reflecting the need to use higher rates of P, K, S and B to reach up to respective critical level for the nutrient. The greenhouse nutrient survey confirmed the deficiencies of nutrients identified through soil analysis. The mean dry matter yield in ranged from 0.42 – 2.60 g/pot, with the lowest dry matter yield in the minus treatments of N, P and S while the highest were observed in the optimum, plus Cu and minus Zn treatment. Relative yields calculated in comparison to the optimum treatment varied from 17.69 to 107.07% (Table 3).

Table 2. Nutrient status of the experimental soils

Nutrient	The amount available mg/kg soils	Optimum*	Above*	Interpretation*
Ca	1820	1202	4810	Sufficient
Mg	398.8	304	1458	Sufficient
K	58.5	196	1173	Deficient
Ca/Mg	4.56	4.1	11.9	Close to optimum
Mg/K	6.8	1.5	4.5	Too high
P	7	48	150	Deficient
S	17	40	150	Deficient
B	0.28	0.8	6.0	Deficient
Cu	6.7	3.0	6.0	Sufficient
Fe	65	30	300	Sufficient
Mn	34.5	12	125	Sufficient
Zn	3	4.0	25.0	Deficient
N**	5	100		Deficient

*According to the interpretive guide (Hunter and Portch 2002)
** Critical level for N according to Hunter (2000)

Table 3. Mean dry matter yield (g/pot) and relative yield (%) in the greenhouse study

Treatments	Status	Mean (g/pot)	Relative yield (%)
Zn	Negative	2.60a	107.07
Cu	positive	2.44a	100.82
Optimum		2.43a	100
Mg	positive	2.39a	98.76
Mo	Negative	2.33a	96.29
Mn	positive	2.32a	95.88
B	Negative	2.24a	92.59
Fe	positive	2.13a	88.06
Ca	Positive	2.07a	85.59
K	Negative	2.01a	83.12
S	Negative	**0.72b**	30.04
P	Negative	**0.46b**	19.03
N	Negative	**0.42b**	17.69

Means with the same letters are not significantly different (P = 0.05)

The mean tomato yields of the field trail varied over the treatment and the season (Table 4) and the statistical analysis indicated a significant treatment effect, seasonal effect as well as treatment and seasonal interaction (p<0.05). During the first season, high NPK treatment gave the highest yield of 60.8 t/ha, whereas the control treatment gave the lowest yield of 20.6 t/ha. The mean yield of the optimum treatment was 38.9 t/ha. The yield increment in treatment 13 over the optimum treatment was 21.8 t/ha, which was statistically significant (p<0.05). Continuous heavy rains and subsequent attacks of fungal diseases in the second season seriously affected the crop giving a very low mean yield compared to the first season. The treatment with no P gave the highest mean yield of 36.2 t/ha, while the control treatment gave the lowest mean yield of 19.4 t/ha. In the third season, high NPK treatment again showed the highest mean yield (49.9 t/ha) whereas the no PK treatment gave the lowest mean yield of 20.9 t/ha. In the fourth season, treatment with high K gave the highest mean yield of 48.5 t/ha followed by high N treatment with a mean yield of 47.4 t/ha. The treatment with no PK gave the lowest yield of 20.3 t/ha (Table 4).

Treatments with higher level of nutrients often showed statistically significant yield increases (p<0.05) over the treatment 16 (Department of Agriculture recommendation) and treatment 17 (control with no fertilizer), with few exceptions (Table 4). The results over the four seasons also indicated that with the depletion of nutrients by providing the same fertility treatment over many seasons to the same plot, the crop responses for major nutrients like N, P and K becomes more apparent. However, there was no response to sulfur even at the 4th season, whereas response to B was seen only in the 4th season. The high NPK treatment gave the highest net profit whereas the control treatment gave the lowest profit. Reasonably high net profits were recorded in treatments with high N, high P and high K treatments.

Table 4. Description of the seventeen fertility treatments tested I the field experiment

Treatment	Description	Nutrients added (kg /ha)			
		Season 1	Season 2	Season 3	Season 4
1	Low N treatment	43.9bcd	24.7ef	35.6abcdef	30.5def
2	**Optimum**	38.9bcde	28.8bcde	35.6abcdef	41.3abcd
3	High N treatment	49.3abc	31.4abcd	47.8ab	47.2ab
4	No P treatment	32.0defg	36.2a	24.3ef	36.6bcd
5	Low P treatment	28.5efg	26.4de	32.7bcdef	32.7cde
6	High P treatment	50.8ab	24.9ef	45.5abc	45.9ab
7	No K treatment	34.9cdef	33.3abcd	39.9abcd	32.0cde
8	Low K treatment	28.8efg	35.3ab	35.3abcdef	33.6cde
9	High K treatment	46.6bc	33.7abc	38.5abcde	48.5a
10	No S treatment	38.7bcde	31.4abcde	39.3abcde	42.6abc
11	No B treatment	41.5bcd	34.0abc	40.0abcd	30.2def
12	High P, K treatment	38.6bcde	34.0abc	32.9bcdef	42.1abcd
13	High N, P, K treatment	60.8a	30.4abcde	49.9a	22.5 ef
14	No P, K treatment	39.7bcde	26.9cde	20.9f	20.3f
15	50% of optimum N,P, K	28.5efg	30.1abcde	30.1def	30.6def
16	Department of Agriculture rec.	24.0fg	28.1cde	25.1def	30.6def
17	Control	20.6g	19.4f	22.3f	20.5f

Conclusions

Initial analysis of the soil at the experimental site indicated deficient levels of N,P,K,S and B, and marginal levels of Zn. The soil had high fixation capacities for P, K, S and B. Optimum fertilizer rates calculated based on initial soil analysis, fixation curves and established critical nutrients levels performed better in the greenhouse while the minus treatments for N, P, K and S gave significantly lower dry matter yields, thus confirming the deficiencies. In the field, the highest tomato yield and net profits were obtained with the treatment providing the highest level of N, P and K (higher than the adjusted optimum rate), while B and S were provided at the adjusted optimum level. The second highest yield was given by the optimum treatment providing all nutrients at the adjusted optimum rate (220 kg N, 160 kg P, 250 kg K, 50 kg S and 1 kg B per hectare). Thus providing nutrients based using this technique was beneficial in terms of tomato yield and profit and this technique can be adapted to formulate site-specific fertilizer recommendation for tomato. Since the treatment with the highest rates of nutrients was superior in terms of both yield and profit, further studies are needed to investigate the change in yield and profit with further increase in the level of nutrients.

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A method to assess the vulnerability of agricultural subsoils to compaction

Matthias Lebert

Soil Scientist and Consultant, Kiel, Germany, Email Matthias.Lebert@t-online.de

Abstract
The method proposed consists of three steps to derive the vulnerability of subsoils to compaction. In the first step, the mechanical susceptibility to compaction is determined by the pre-compression stress with pedotransfer functions. In the second step, soil structural quality of subsoils is determined by the evaluation of soil physical properties as air capacity, saturated water conductivity and packing density. In the third step, vulnerability to compaction is derived by combining the mechanical susceptibility to compaction with the soil structural quality. The method is based on the evaluation of actually analysed soil physical data from 1300 representative agricultural subsoils in Germany, offered by the soil surveys of the federal states. The results are shown in maps of 1:1.000.000 scale. At the water content of 100 % field capacity, about 60 % of the German subsoils are high vulnerable to compaction, including marshlands, clayey river sediments, glacial loams, loessian soils, periglacial clays and loamy and clayey soils derived from weather beaten rocks and sediments. Pure and loamy sands have low vulnerability. At the water content of 80 % field capacity, low, medium and high vulnerability are distributed about one third each over the arable area in Germany.

Key Words
Soil compaction, soil structure, soil protection strategies, soil risks mapping

Introduction
Compaction reduces fertility, aeration and permeability of soils. It impairs soil functions and is regarded as a soil threat that can become a risk for sustainable land use. Soil compaction is subject of various national and international legislative frameworks. In order to set up national and international soil protection strategies, maps for the identification and quantification of the risk of subsoil compaction are essential.

Methods
Soils and data
The investigations were done at a random sample of 1300 representative subsoils of arable land in Germany. The analytical data of the soils were offered by the soil surveys of the German federal states. The majority of the sampling has been done after 1990. The following data were used for evaluations: geological origin of the soil, soil type, soil horizons, packing density, texture, skeleton, organic matter content, dry bulk density, air capacity, available water capacity, non-available water capacity, saturated water conductivity, cohesion and angle of internal friction.

Assessment of susceptibility to compaction by pedotransfer functions
In Germany, three sets of pedotransfer functions exist to assess the mechanical pre-compression stress of soils (DVWK M 234 1995; DVWK M 901 2001; DIN V 19688 2001). Lebert (2008) verified the following functions for general use to German agricultural subsoils: DVWK M 234 for pure and loamy sands and DIN V 19688 for silts, loams and clays and for silty and clayey sands. The verified functions were used in the paper to derive pre-compression stress and the corresponding susceptibility to compaction, which are classified according to a proposal by Lebert and Schäfer (2005) (Table 1).

Table 1. Classification of pre-compression stress and of the susceptibility to compaction

Pre-compression stress			Susceptibility to compaction
kPa	Class Nr.	Name of class	Name of class
< 80	5	very low	very high
80 - < 120	4	low	high
120 - < 160	3	medium	medium
160 - < 200	2	high	low
≥ 200	1	very high	very low

According to the verified pedotransfer functions Lebert (2008) determined the pre-compression stress for typical, representative subsoils in Germany, and developed a simplified classification scheme, depending on the soil texture and the packing density of the soils (Table 2). According to that scheme, the susceptibility can be mapped in any scale.

Table 2. Class of susceptibility to compaction at the water content of field capacity (pF 1,8) of German subsoils depending on soil texture group (Ad Hoc AG Boden 2005) and packing density (PD).

Soil texture group	Class of mechanical susceptibility to compaction PD 1	PD 2	PD 3	PD 4	PD 5
pure sands	5	3	1	1	1
loamy sands	5	4	2	1	1
silty sands	5	5	4	3	2
sandy loams	5	5	4	3	3
sandy silts	5	4	4	3	2
loamy silts	5	4	3	3	2
clayey silts, normal loams	5	5	4	4	3
clayey loams	5	5	5	4	4
silty clays, loamy clays	5	5	4	4	4

Table 2 shows the susceptibility to compaction at the water content of field capacity (pF 1,8) by pedotransfer functions for the pre-compression stress. To consider the effects of desiccation on susceptibility of soils an algorithm was used, proposed by Rücknagel (2006) (Table 3). The reduction of the susceptibility class at field capacity (pF 1,8) is depending on the initial class and on the degree of desiccation in % field capacity. No further reductions are made to the lowest class of susceptibility (class 1 = very low).

Table 3. Reduction of the class of susceptibility to compaction depending on the degree of desiccation in % of field capacity.

Initial class at field capacity (pF 1,8)	Reduction of susceptibility class to compaction in classes at % field capacity: 90	80	70	60	50
5	-1	-1	-2	-3	-4
4	-1	-1	-2	-3	-3
3	-1	-2	-2	-2	-2
2	-1	-1	-1	-1	-1
1	no reductions on lowest class				

Assessment of soil structure quality

Soil structure quality in this paper is defined as the quality of those soil functions that are strongly and directly affected by compaction, i.e. soil aeration, soil permeability and rootability.

Table 4. Classification of soil structure quality.

a) Packing density (-)	b) Air capacity (% vol.)	c) Saturated water conductivity (cm/d)	Class	Name of class	Class of soil structure quality
≥ 1,8	< 5	< 10	5	very low	Round off from
1,7 - < 1,8	5 - < 7	10 - < 40	4	low	average of classes a),
1,6 - < 1,7	7 - < 13	40 - < 100	3	medium	b), c) =
1,4 - < 1,6	13 - < 26	100 - < 300	2	high	
< 1,4	≥ 26	≥ 300	1	very high	(a + b + c) / 3

In this paper, a set of thresholds is used as proposed by Lebert *et al*. (2007). A set of three parameters, air capacity, saturated water conductivity and packing density, allows the detection of soil structure damage by compaction. A distinct identification of soil structure damage is possible when all three parameters exceed the limits of a sufficient soil structure at the same time: the air capacity is less than 5 % (vol.), the saturated water conductivity is below 10 cm/d, and the soil is classified into classes 4 (= dense) or 5 (= very dense) by the soil structure valuation of packing density. The classification of soil structure quality in this paper corresponds to these thresholds in the class "very low" (Table 4). The further classification corresponds to the ratings of the German soil survey (Ad Hoc AG Boden 2005). The class of soil structure quality is calculated as a round off from the average value of the single parameters.

Assessment of vulnerability to compaction
The classification of the vulnerability of subsoils to compaction is done by a combination of the two above described parameters: soil structure quality and mechanical susceptibility to compaction. It follows the principle that vulnerability is high, when soil structure quality is low and simultaneously, the mechanical susceptibility to compaction is high. There are 5 classes of vulnerability to compaction, very high = 5, high = 4, medium = 3, low = 2 and very low = 1. The result is a 1:1 weighed average of the class of susceptibility (Tables 2 and 3) and the soil structure quality class (Table 4). In Table 5, three examples for the determination of the vulnerability class are given.

Table 5. Examples for the determination of the class of vulnerability to compaction.

a) Class of susceptibility (Table 2)	b) Water content (% field capacity)	c) Reductions in classes by water content (Table 3)	d) Final class of susceptibility	e) Class of soil structure quality (Table 4)	Class of vulnerability (1:1 average of d) and e), round off)
4	100	0	4	4	(4 + 4)/2 = 4,0 = 4
4	70	-2	2	3	(2 + 3)/2 = 2,5 = 3
2	90	-1	1	3	(1 + 3)/2 = 2,0 = 2

Results

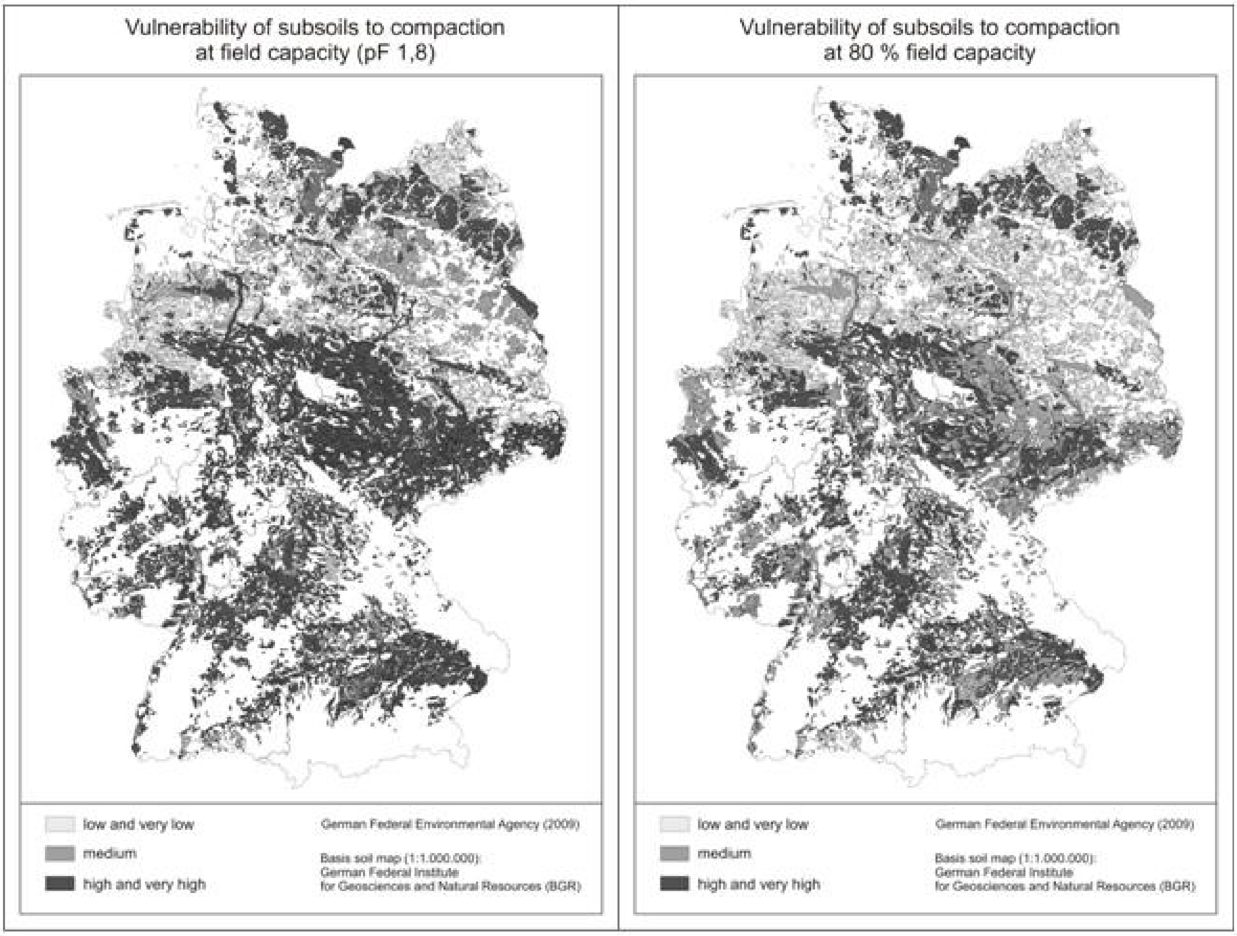

Figure 1. Vulnerability to compaction of agricultural subsoils in Germany in the map 1:1.000.000 at two water contents: field capacity (pF 1,8) and 80% field capacity.

Figure 1 shows the results of the assessment of vulnerability to compaction at two different water contents: 100 % field capacity (= pF 1,8) and 80 % field capacity in the 1:1.000.000 map of Germany. Around 60 % of the German agricultural subsoils are high and very high vulnerable to compaction at the water content of field capacity. Nearly all loamy, silty and clayey soils are representing these classes. Poor loamy sands have medium vulnerability and only pure sands are classified as low vulnerable. The vulnerability at field capacity can be considered as a worst case, because the real water content in subsoils during field operations is lower than field capacity. A water content of 80% field capacity is likely to be more representative during wheeling in subsoils. At that water content, each of the classes “low and very low”, “medium” and “high and very high” nearly represent a third of the German arable land. Pure sands and poor loamy sands are low and very low vulnerable. Medium vulnerable are loessian sands, loess soils mixed with weather beaten materials, loessian soils of loamy silty texture, loamy and clayey soils derived from weather beaten rocks and hard sediments with high amount of skeleton, silty river sediments and periglacial silts. High vulnerable are soils of the marshlands, clayey river sediments, glacial loams, loess soils with clayey silty texture, periglacial clays, loamy and clayey soils derived from weather beaten rocks and hard sediments with low amount of skeleton (< 25 % Vol.) and loamy moraines.

Conclusion

The results of mapping in the 1:1.000.000 scale show, that large areas of German arable land are highly susceptible and vulnerable to compaction. The results underline the importance of the protection of soils against compaction. The avoidance of subsoil compaction is evident for a sustainable land use, because subsoil compaction is a high risk for soil functions. For the prevention of soils against compaction soil physically based approaches to adjust the mechanical stresses to the subsoils mechanical strength are mandatory.

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A multivariate approach to site selection for comparative soil studies

S.C. Löhr[A,B], J. Hodgkinson[C] and S. Fraser[C]

[A] Discipline of Biogeosciences, Queensland University of Technology, Brisbane, QLD, Australia, Email s.loehr@qut.edu.au
[B] Institute for Sustainable Resources, Queensland University of Technology, Brisbane, QLD, Australia.
[C] CSIRO Exploration and Mining, Queensland Centre for Advanced Technologies, Pullenvale, QLD, Australia.

Abstract
Careful site selection is of great importance in comparative soil studies. Any conclusions based on the comparison of sites which have been subject to different genetic histories and processes are likely to be erroneous. This article proposes a multivariate site selection method based on Kohonen's self-organising maps. The method is designed to group similar samples and so permit the identification of sites that are suitable for comparative studies. A case study is presented to illustrate the method.

Key Words
Site selection, comparative study, multivariate, self-organising maps, soil water.

Introduction
An experimental approach can be effectively used to distinguish between causal and correlative relationships in the soil environment. The value of employing controlled experiments to study soil-forming processes has recently been reiterated by Bockheim and Gennadiyev (2009). In many cases, however, such an approach is impractical, primarily because of the long time-scales involved in most soil-forming processes. Where this is the case, comparative studies can provide similar information, provided that the sites to be compared are carefully selected. Examples of studies in which a comparative approach has been employed are common. They range from the use of chronosequences to determine the effect of soil age on a range of soil properties (Calero *et al.* 2009) to the comparison of soils formed in different parent materials to determine the effect of parent materials on soil organic carbon dynamics (Heckman *et al.* 2009). Indeed, much of our understanding of soil processes is derived from studies that employ a comparative rather than an experimental approach.

Site selection for comparative studies
Site selection is of great importance in comparative studies. This is because the soils need to be sufficiently similar, in terms of their genetic history and the processes currently operating within them, for their comparison to be valid. Ideally, the sites selected for comparative purposes will be identical, apart from the differences that can be attributed to the process or factor being studied (i.e. age, parent material, vegetation, fire history, landscape position, and climate). Given that no two soils are identical, this ideal situation will never be attained. Nevertheless, the conclusions based on the comparison of sites subject to different genetic histories and processes are likely to be erroneous. Thus, it is of great importance to select sites that are suitable for comparative studies. Unfortunately, this is often not tested, or only considered in a purely qualitative manner.

New site selection method
This work proposes a multivariate site selection method for comparative studies, based on the self-organising maps (SOM) data analysis method (Kohonen 2001). This method is designed to ensure that the selected sites are suitable for comparison. In other words, the method can be used to identify sites that are sufficiently similar so that their comparison is valid.

Case study
We present a case study in which we employ the method to select sites for a study on the effect of vegetation type on soil water composition. The study area lies within a coastal catchment in South-East Queensland (Australia), and extensive parts of the catchment have been cleared of native vegetation to establish exotic pine plantation since the 1950's. The study investigates the effect of vegetation (pine plantation *vs* remnant native forest) on the speciation of iron (Fe) in soil water. Soil water is collected *in situ*, using MacroRhizon (Eijkelcamp Agrisearch) micro-lysimeters installed at 50 cm depth. Thus, similar soil types are required for micro-lysimeter installation at the comparison sites.

Methods

Self organising maps

A detailed explanation of self organising maps is outside of the scope of this short contribution and we refer the readers to Kohonen (Kohonen 2001), or Astel *et al*. (2007) for an example of SOM analysis applied to a large environmental dataset. In brief, the self organising map can be considered a data visualisation and analysis tool. Although it is usually considered an exploratory tool, the method can be used to perform function fitting, prediction or estimation, clustering, pattern recognition and classification (Fraser and Dickson 2007). In this paper we employ SOM as a clustering tool because it allows the mixing of continuous and categorical input data types. In addition, samples with missing data values can be included in the analysis. In a previous study we have shown that SOM is able to group samples that have been affected by the same pedogenic processes, using only easily obtained data such as physical and chemical properties of soils and their topographic position (Löhr *et al.* 2010).

Selection of site variables

In this study we use a subset of the data from our previous study to identify three paired sites (six in total) for a comparative study of the effect of vegetation on the speciation of Fe in soil water samples.
In spite of the uniform geology and climate at all potential comparison sites, the sites are found at different landscape positions and within different soil types. The soils are characterised by distinct chemical and physical properties. Exotic pine plantations have been established relatively recently and are not expected to have affected bulk soil properties. Thus, it was deemed appropriate to select comparison sites based on similarities in landscape position and bulk soil properties (chemical and physical). Accordingly, the variables listed in Table 1 were included in the SOM analysis. The variable 'vegetation type' is excluded in order to permit clustering of similar sites with differing vegetation.

Table 1. Variables included in SOM analysis

Terrain	Gamma-ray spectrometry (GRS)	Soil chemistry	Soil physical properties	Clay mineralogy
Elevation, Slope, Curvature, Topographic Wetness Index	U, Th	1 M HCl-extractable: Na, Mg, Al, K, Ca, Mn, Fe and Zn	Organic carbon, pH, EC, Fe-concretion, clay fraction	Kaolinite, Vermiculite, Illite, Illite-Smectite

Results

After SOM analysis, the 120 samples were assigned to 56 best matching units (BMU's or clusters); between 1 and 6 samples were assigned to each cluster (by the SOM process). Paired sites for the comparative soil moisture study were selected from these and are shown in Table 2. Criteria for paired site selection were a) high overall similarity, as expressed by allocation to the same cluster and low q-error (a measure of the 'distance' of a sample from the cluster centroid) and b) different associated vegetation types (exotic pine plantation *vs* native vegetation). In order to independently verify that the selected sites are sufficiently similar for comparative purposes, the soil type at these locations was classified according to the Australian Soil Classification (Isbell 2002).

Discussion

Recent work has shown that the SOM approach is able to identify and group sites at which similar pedogenic and geochemical processes are operating (Löhr *et al.* 2010). These groupings remained meaningful even when the initial clusters (the best match units) were aggregated into larger groupings using k-means clustering. In the method proposed here, samples are not aggregated into large clusters, but retained in a greater number of small clusters. Thus, samples with moderate similarity remain in separate groups, helping to ensure that the paired samples display high overall similarity.
Nevertheless, the results demonstrate that the paired sites are not identical (Table 2). Sites 30 and 32, for instance, have substantially different extractable Fe and Mg concentrations. They are classified as different soil types and are likely to have formed as a result of different genetic processes. Sites 58 and 85, on the other hand, are classified as the same soil type. Although the sites have different slopes and an extractable Fe concentration that differs by a factor of two, their overall similarity cannot be disputed. The same is true of both sites in pair C. While these soils are classed as different soil types (mostly due to a greater degree of pedogenesis in site 21), the differences are minor.

Clearly, the successful use of the proposed site selection method depends on the data used to compare potential comparison sites. Apart from the terrain attributes, the data used here to select sites are based on analysis of the top 30 cm of soil only. This has resulted in paired sites at which the upper soil horizons are indeed similar. However, the use of exclusively surficial data is not sufficient to ensure selection of similar locations in all instances, as shown by site pair A. We suggest that the performance of the method in the case study can be improved by incorporating data of soil properties at greater depths into the analysis. Ideally, the comparison sites can be selected from the potential comparison sites grouped within a cluster after field comparison of these sites.
Employing a quantitative, data-driven approach for site selection has a number of advantages. In addition to minimising the possibility of invalid comparisons due to unsuitable site selection, the researcher can gain an understanding of the variability of the soil properties in the study area by comparing a number of potential sites using quantitative data. It is therefore possible to conduct a comparative study and include a consideration of the effects of subtle differences between the comparison sites, as well as spatial variability more generally.

Table 2. Properties of paired sites selected from 120 samples clustered into groups of similar sampling locations using SOM

Site parameter	PAIR A		PAIR B		PAIR C	
Site ID	30	32	58	85	21	41
BMU	16	16	20	20	55	55
q-error	1.6	1.2	2.7	2.4	1.4	2.0
Vegetation –plantation	Yes	No	Yes	No	Yes	No
Vegetation – native	No	Yes	No	Yes	No	Yes
Terrain curvature	0	-0.17	0	-0.31	0	0
Slope (%)	2.5	6.1	3.1	12.4	3.6	4.4
Elevation	31	17	51	31	31	28
TWI	10.6	9.7	9.1	8.3	10.0	8.4
K	7.18	3.61	14.59	18.16	10.18	16.16
Al	286	360	480	300	114	138
Ca	19.9	9.2	69.9	31.9	25.9	81.7
Fe	418.8	106.2	680	359.2	61.9	111.7
Mg	69.8	14.8	32	71.8	65.9	97.8
Mn	<0.4	<0.4	0.4	5.0	<0.4	0.4
Na	<4.4	<4.4	8.9	<4.4	10.4	14.0
Zn	<0.5	<0.5	6.4	4.19	<0.5	<0.5
Th (GRS)	1.7	1.9	2.6	2.9	2.0	2.3
U (GRS)	0.8	0.7	0.9	0.7	0.7	0.6
Clay fraction (%)	11.1	9.2	11.2	10.5	9.3	5.8
Vermiculite	2	1	3	2	0	0
Illite/Smectite	0	0	1	1	0	0
Illite	0	0	0	1	0	0
Kaolinite	1	1	3	1	0	0
Fe concretions (%)	1.4	1.3	0.4	1.5	5.4	0
pH	5.32	5.10	5.13	5.20	4.25	4.16
EC	6.4	9.6	18.3	10.5	32.1	33.3
Loss on ignition (%)	1.52	1.31	1.72	1.17	3.12	3.39
Soil type (Australian Soil Classification)	Mottled, Grey Kurosol	Humosesquic, Aeric Podosol	Mottled, Brown Kandosol	Mottled, Brown Kandosol	Humosesquic, Aeric Podosol	Acidic, Arenic Rudosol

Conclusion

We propose a multivariate approach to site selection for comparative soil studies. The method is based on the SOM data analysis method and is designed to ensure that selected sites are sufficiently similar so that their comparison is valid. Careful selection of the input variables is essential in order to a) exclude soil properties that may have been affected by the soil process of interest and b) include sufficient data to avoid clustering of sites which are dissimilar.

The case study showed the successful selection of two sets of comparison sites out of a total of 120 candidate locations. A third selected site pair were significantly different, and illustrated the importance of field validation of comparison sites. Nevertheless, a process-sensitive method such as the self-organising maps can prove a robust means of selecting locations suitable for comparative studies.

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A new buffer that imitates the SMP solution for determining potential acidity of Brazilian soils

Maria Alice Santanna[B], João Kaminski[B], Danilo Rheinheimer dos Santos[B], Jaderson dos Anjos[B], Cesar Cella[B], Diogo Sebastian Pippi Calegari[B]

[A]Department of Physical, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brasil, Email maria.alice.santanna@gmail.com
[B]Department of Soil Science, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brasil, Email joao.kaminski@gmal.com

Abstract
A buffer (TSM) was developed to reproduce the behavior of the SMP buffer in the estimate of potential acidity of Brazilian acid soils. This buffer contains four weak bases (TEA, MES, calcium acetate and imidazole) and calcium chloride to control the ionic strength. The efficiency of the new buffer in imitate the SMP was evaluated in twenty one Brazilian soils, whose potential acidity was measured by wet incubation with calcium carbonate, employing treatments 0, 50, 75, 100, 125 and 150% of the potential acidity previously estimate by chemical method. The H+Al measured correspond to the amount of calcium carbonate of the treatment that achieved pH 7, or was obtained by linear interpolation between the treatments below and above pH 7. In the unlimed samples the pH of soil-buffer suspension was determined and these values were plotted against the H+Al measured and fitted by regression for each one of the buffers. The TSM pH values were similar to the SMP ones for the same soils. Thus, the new buffer is a reliable predictor of potential acidity of tropical and subtropical soils and it is able to replace the SMP buffer, with the advantage that it does not contain hazardous substances.

Key Words
Soil acidity, SMP buffer, liming, hazardous chemicals, tropical soils

Introduction
The SMP solution, developed by Shoemaker *et al*. (1961) is one of the most employed buffers to evaluate potential acidity of Brazilian soils, since it is suitable for soils with high lime requirements and significant resources of exchangeable aluminum, like those of Southern Brazil, as well as for soils with moderate or low acidity, such as those of Cerrado region. Routine soil testing laboratories usually use SMP method because it is quick, relatively low cost and presents good reproducibility. However, the accuracy of this method must be verified by calibration (soil-lime incubation studies) on the soils routinely tested. The SMP solution contains four chemicals that act as weak bases to buffer the pH (triethanolamine, p-nitrophenol, potassium chromate and calcium acetate), along with calcium chloride to control the solution ionic strength. Among these substances, two are considered hazardous: p-nitrophenol and the chromate ion (CrO_4^{-2}), in which the chromium is hexavalent and carcinogenic (USEPA 1998). The immediate effects of human exposure by inhalation, skin contact or ingestion of p-nitrophenol may be headache, nausea, and drowsiness (Huluka 2005). The prolonged exposure to p-nitrophenol should be matter of major concern, especially for operators of soil routine analysis labs. Braunbeck (1989) studied the effect of prolonged exposure of zebra fish to p-nitrophenol. He observed symptoms of degenerative transformation of the liver tissue of 25% of these fishes, following prolonged exposure to 1 mg/l of p-nitrophenol in the water. After the SMP-pH determination these toxic substances remain in the soil suspension residues. Another drawback of SMP method is that the routine use of the glass combined pH electrode to measure the SMP pH promotes the degradation of the electrode reference junction (Hoskins and Erich 2008). In recent years, there is a trend to focus research on the development of more environmentally friendly buffers. A buffer that does not contain hazardous substances, in which imidazole and MES [2-(N-morpholino) ethanesulfonic acid] take the places of p-nitrophenol and chromate, respectively, was developed to mimic the SMP buffer used in some of the USA soils (Sikora 2006). However, the Sikora buffer does not imitate the adapted SMP buffer used in Southern Brazil (Kaminski *et al.* 2007). In this sense, the aim of this work is to develop and test a new solution that mimics the adapted SMP as predictor of potential acidity of soils of tropical and subtropical regions. The new buffer contains some of the bases of the SMP and others of the Sikora buffer, with their concentrations adjusted to give the same buffer capacity of the SMP method.

Methods

Twenty one unlimed soils samples were collected from the 0-20 cm layer of different physiographic regions of Brazil: eleven from lowlands and seven from highlands of the Rio Grande do Sul state and three from the Cerrado region. Chemical and physical analysis were performed: size distribution of particles, exchangeable Al^{3+} with 1 mol/l KCl solution and organic matter content by wet digestion. These results are presented in Table 1.

Table 1. General characteristic of unlimed soils.

Soil	Clay[1]	Sand[1]	Silt[1]	OM[2]	pH[2]	Ca[2]	Mg[2]	Al[2]	pH[2]	pH[3]	H+Al[4]
	---------------- g/kg			-----------------	H_2O	--------- cmo$_c$/kg		--------	SMP	TSM	cmol$_c$/kg
Lowland	84	689	228	11	4.9	1.01	0.30	0.55	6.3	6.4	6.07
	293	104	603	36	5.0	13.2	4.25	0.15	5.9	6.1	12.17
	160	509	331	15	4.1	0.41	0.09	2.00	5.5	5.7	8.38
	206	215	579	27	4.4	5.94	1.63	0.98	5.6	5.6	11.21
	195	391	413	17	4.4	3.34	1.14	1.38	5.8	5.8	10.73
	377	62	561	22	5.1	12.33	3.74	0.43	5.9	5.9	10.62
	56	782	162	12	4.5	0.28	0.16	0.43	6.7	6.6	4.22
	59	763	177	13	5.4	1.59	0.77	0.00	6.8	6.7	4.02
	164	544	292	23	4.6	2.55	0.84	0.70	6.0	5.9	8.46
	64	776	159	15	4.6	1.59	0.71	0.45	6.3	6.4	4.86
	139	585	276	18	4.4	1.71	0.79	0.88	5.9	6.0	7.13
Highland	375	242	383	57	4.1	3.98	1.33	1.75	4.9	5.0	18.00
	479	175	346	63	4.0	2.3	1.07	3.90	4.5	4.6	28.20
	497	161	343	82	4.4	1.49	0.83	4.65	4.4	4.4	35.95
	531	111	359	52	4.1	2.41	1.43	2.75	4.7	4.7	24.89
	480	172	348	42	4.3	1.93	1.01	3.55	4.7	4.7	19.68
	544	135	321	58	4.0	2.55	1.69	4.03	4.5	4.5	29.64
	497	147	356	63	4.3	2.84	1.71	2.93	4.7	4.7	25.86
Cerrado	601	164	235	40	5.2	3.2	1.51	0.10	5.8	5.9	9.99
	230	730	40	23	5.0	1.9	0.54	0.23	6.2	6.2	6.56
	293	649	58	29	4.9	2.48	1.09	0.30	6.0	6.0	10.41

(1)EMBRAPA (1997); (2)Tedesco et al. (1995); (3)TSM buffer; (4) Data from soil incubation results (H+Al measured)

Soil samples (1.00 kg), in quadruplicate, were submitted to the application of increasing doses of calcium carbonate, equivalents to 0, 50, 75, 100, 125, 150% of the potential acidity estimated by chemical method and wet incubated for130 days, with weekly revolving and aeration. Then, soils samples were air dried and grinded, before performing the pH in water and the H+Al measurements.

The adapted SMP solution contains calcium chloride dihydrate ($CaCl_2.H_2O$, 147.01 g/mol) 0.721 mol/l; triethanolamine [$N(CH_2CH_2OH)_3$, 149.19 g/mol] 37.5 mmol/l; ρ-nitrophenol ($O_2NC_6H_4OH$, 139.11 g/mol) 26.2 mmol/l, potassium chromate (K_2CrO_4, 194.19 g/mol) 30.9 mmol/l, calcium acetate [$Ca(CH_3COO)_2$, 158.17 g/mol] 12.6 mmol/l. The pH-SMP value is measured in a soil suspension prepared with the volume proportions 1:2:2 (SMP buffer: water: soil) (Tedesco *et al.* 1995). The pH-SMP was determined in unlimed soils and in soils treated with 50% of the potential acidity.

Results

The developed new buffer, named *Santa Maria* (TSM), was prepared with the following composition: triethanolamine [$N (CH_2CH_2OH)_3$, 149.19 g/mol] 28 mmol/l /; imidazole ($C_3H_4N_2$, 68.08 g/mol) 15.5 mmol/l, MES [2-(N-morpholino) ethanesulfonic acid hydrate] ($C_6H_{13}NO_4S.H_2O$, 213.25 g/mol) 47.2 mmol/l; calcium acetate [$Ca (CH_3COO)$ 158.17 g/mol] 25.4 mmol/l and calcium chloride dihydrate ($CaCl_2.H_2O$, 147.01 g/mol) 720 mmol/l. The final pH was adjusted to 7.5 with NaOH 40% (w/w). The pH TSM is measured in soil suspension with the same volume proportions above described for the adapted SMP.

Table 1 shows data of unlimed soils. The measured H+Al range from 4.02 to 35.95 cmol$_c$/kg. Organic matter content (OM) vary from 11 to 82 g/kg, with the higher values obtained in highland soils, which are all above 42 g/kg. Exchangeable Al range from zero to 4.65 cmol$_c$/kg, with the lower values corresponding to Cerrado soils (<0.30 cmol$_c$/kg). Therefore, this is a suitable group of soils for this study, since it present a broad range of soil acidity and physical and chemical characteristics. Currently, most of the agricultural soils have been already limed. For this reason limed soils were included in this study to evaluate the buffers performance in this kind of soil. The liming rate of 50% of the potential acidity was chosen and these data are shown in Table 2. As expected, lower values of potential acidity were obtained, which range from 1.87 to 22.99 $cmol_c$/kg.

Table 2. Soil chemical characteristic after lime incubation.

Soil	pH H_2O(1)	pH SMP(1)	pH TSM(2)	Ca(1)	Mg(1)	Al(1)	H+Al measured(3)
				------------------------ $cmol_c$/kg	-------------------------		
Lowland	5.0	6.6	6.6	3.01	0.36	0.15	3.62
	5.6	6.2	6.2	16.08	3.98	0.00	9.02
	6.0	6.6	6.7	4.78	0.10	0.00	3.18
	5.5	6.3	6.4	10.27	1.59	0.00	6.91
	5.4	6.5	6.6	7.86	1.15	0.00	5.53
	5.7	6.2	6.3	15.12	3.67	0.10	7.12
	5.4	6.9	7.0	1.76	0.17	0.10	2.37
	6.4	7.0	7.1	3.16	0.55	0.00	1.87
	5.0	6.2	6.3	5.31	0.84	0.13	5.31
	5.1	6.7	6.7	3.10	0.72	0.00	3.01
	5.6	6.7	6.6	4.35	0.76	0.00	3.98
Highland	4.4	5.3	5.5	9.69	1.33	0.43	11.84
	4.4	5.1	5.3	9.12	1.01	0.65	20.35
	4.7	5.3	5.4	14.94	0.88	0.20	21.46
	4.3	5.1	5.1	8.76	1.42	0.65	18.74
	4.8	5.8	5.9	9.40	1.04	0.15	11.83
	4.3	5.0	5.2	8.01	1.71	1.03	22.99
	4.4	5.2	5.3	9.54	1.77	0.73	18.76
Cerrado	5.7	6.1	6.1	5.06	1.44	0.00	7.53
	5.9	6.7	6.7	3.97	0.47	0.00	3.41
	5.6	6.3	6.4	4.82	1.00	0.10	6.91

(1)Tedesco et al. (1995); (2) TSM buffer; (3) Data obtained from soil incubation

When a soil sample is put in contact with the buffer solution, a decreasing of pH is observed. For unlimed soils, the obtained values of pH-SMP range from 4.5 to 6.8, while the pH-TSM varies from 4.5 to 6.7. Table 2 shows results obtained for these soils after liming (treatment 50) where these values, as expected, increase: pH-SMP vary from 5.0 to 7.0 and the pH-TSM, from 5.1 to 7.1. A plot of pH-TSM versus pH-SMP, including unlimed and limed (treatment 50) soils, gives a linear relation and the equation pH-TSM = 0.2858 + 0.9596 pH-SMP (R^2 = 0.9902). The angular coefficient is close to 1.0 and the linear one is not far from zero, which means that the TSM buffer reproduces quite well the SMP behavior.

Furthermore, from the relation between measured H+Al and pH-SMP or pH-TSM (Figure 1), it is possible to see that the exponential decay of H+Al values as a function of pH is very similar for both buffers.

The replacement of SMP by TSM would avoid the production of around 1,500 litres of hazardous residues of soil analysis per year in Southern Brazil. If this toxic waste containing chromate and p-nitrophenol is drained down the sink it may contaminate water resources. On the other hand, the regulation of its disposal for off-site treatment increases laboratorial costs. The hexavalent chromium present in the chromate ion is carcinogenic (USEPA 1998). The p-nitrophenol ingestion or inhalation can cause headache, nausea, and drowsiness (Huluka 2005) and it was observed abnormal growth of tissues of fishes submitted to prolonged exposure to 1 mg/l of this compound in water (Braunbeck 1989).

Conclusion

The new buffer is a reliable predictor of potential acidity and it is able to replace the SMP buffer, with the advantage that it does not contain hazardous substances, avoiding contamination of water resources with chromate and p-nitrophenol soil analysis residues. Besides, the lab operator will not undergo the healthy risks of manipulation of chromate and p-nitrophenol, which is especially important at routine analysis labs, and the replacement of SMP by TSM will not change the laboratorial routine already established.

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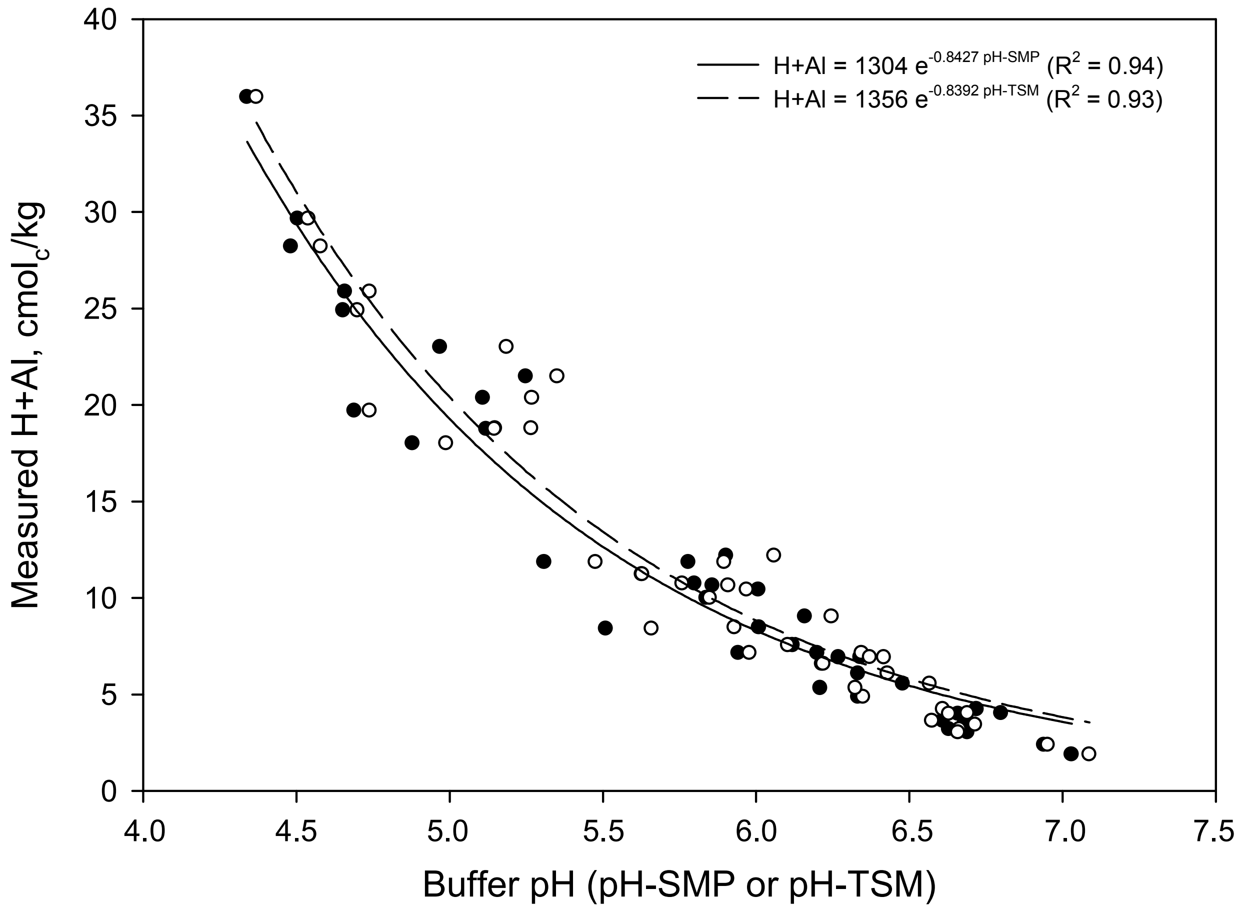

Figure 1. Relationship between the buffer pH (pH-SMP or pH-Santa Maria) and the potential acidity.

A quantitative assessment of phosphorus forms in Australian soils

Ashlea Doolette[A], Ronald Smernik[A] and Warwick Dougherty[B]

[A]School of Agriculture, Food and Wine, University of Adelaide, Waite Campus Urrbrae, SA, 5064, Australia.
[B]Department of Primary Industries, Industry and Investment, New South Wales, Locked Bag 4, Richmond, NSW, 2753, Australia.
Email ashlea.doolette@adelaide.edu.au

Abstract
Solution ^{31}P nuclear magnetic resonance (NMR) spectroscopy is by far the most widely-used spectroscopic technique for the speciation of soil organic P, but is yet to be used to characterise a wide range of Australian soils. Therefore, using this technique we analysed the NaOH-EDTA extracts of 18 diverse Australian soils. The majority of ^{31}P NMR signal was assigned to orthophosphate, representing 46 to 90% of total NaOH-EDTA extractable P. Orthophosphate diesters and pyrophosphate were present in all soil extracts, their concentrations ranging from 5 to 87 mg/kg (1-5% of total NaOH-EDTA extractable P) and up to 62 mg/kg (5% of total NaOH-EDTA extractable P) respectively. Up to 12 well-resolved orthophosphate monoesters resonances were identified (α- & β- glycerophosphate, *myo*-inositol hexa*kis*phosphate (phytate), adenosine-5′-monophosphate (AMP), *scyllo*-Inositol hexa*kis*phosphate). Orthophosphate monoesters were dominated by α- & β-glycerophosphate and phytate. All three compounds were assigned in all spectra with concentrations of α- & β glycerophosphate ranging from 1–5% and phytate up to 9% of total NaOH-EDTA extractable P. However, phytate concentrations were considerably lower than values determined previously for other soils. As well as numerous sharp resonances in the monoester region which we attributed to specific P-containing compounds, our results showed a large proportion of monoester P (24–65%) could be assigned to a single broad feature. We suggest that this broad signal is due to organic P found in large molecules such as humic acids.

Key Words
Organic phosphorus, ^{31}P NMR, Australian soils

Introduction
Phosphorus (P) is an essential nutrient required for plant growth. Although most soils contain large reserves of inorganic P, most of it is locked up in insoluble and tightly-bound forms. Organic P is not directly available to plants but can be converted into available inorganic P through hydrolysis or mineralization. The rate of P release from organic P forms depends partly on the specific organic P compounds present. Organic P contents vary appreciably among soils, but can represent up to 80% of total soil P (Dalal 1977). Australian soils are characteristically low in P for a variety of reasons. Perhaps most significantly, they are predominantly derived from sedimentary rocks, including sandstone, which are generally low in P. Additionally, over long periods of time these soils have experienced P losses due to leaching and erosion. Australian soils resistant to P deficiency are primarily those which occur in high rainfall zones where organic matter can accumulate (e.g. deep forested soils), or other areas where high iron (Fe) content has led to the retention of P by sesquioxides (Handreck 1997). However, not since Williams and Anderson (1968) has an attempt been made characterise the P forms in Australian soils. Therefore, the accurate characterisation of Australian soils will be useful in terms of aiding future efforts to access various P pools and manage P in agricultural systems (Cornish 2009a; b; Evans and Condon 2009; Guppy and McLaughlin 2009).

Solution ^{31}P nuclear magnetic resonance (NMR) spectroscopy is by far the most widely-used technique for the speciation of soil organic P, the main reason being that of all the currently available techniques, it provides the most detailed and accurate information. In this study we use spiking experiments, and a modified method of spectral deconvolution to assess a wide range of Australian soils to provide a quantitative assessment of the P forms present.

Methods
NaOH-EDTA extraction
Eighteen soil samples were ground to pass through a 2-mm sieve prior to extraction. Soils were extracted in triplicate using the standard methods of Cade-Menun and Preston (1996). This involved shaking 2.0 g of soil with 40 mL of 0.25 *M* NaOH and 0.05 *M* Na_2EDTA for 16 h. The extracts were centrifuged (1400 x *g*) for 10

min and filtered using Whatman no. 42 filter paper. A 15 mL aliquot was immediately frozen and freeze-dried for NMR analysis. Triplicate sub-samples of the supernatant were also taken to determine the total P concentrations using nitric acid digestion and subsequent analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES).

NMR analysis of NaOH-EDTA extracts

Triplicate freeze-dried NaOH-EDTA extracts for each soil were combined for NMR analysis. A 500 mg sub-sample of each composite extract was ground, re-dissolved in 5 mL of deionised water and centrifuged at 1400 *g* for 20 min. The supernatant solution (3.5 mL) and D_2O (0.3 mL) were placed in a 10 mm NMR tube. Solution ^{31}P NMR spectra were acquired at 24ºC on a Varian INOVA400 NMR spectrometer (Varian, Palo Alta, CA) at a ^{31}P frequency of 161.9 MHz. Recovery delays ranged from 10 to 30 s and were set to at least five times the T_1 value of the orthophosphate resonance determined in preliminary inversion-recovery experiments. We used a 90º pulse of 32 to 45 µs, an acquisition time of 1.0 s and broadband ^1H decoupling. Between 3224 and 49000 scans were acquired for each sample, depending on the P concentration of the freeze-dried extract. Chemical shifts were referenced to β-glycerophosphate at 4.63 ppm according to Doolette *et al.* (2009).

Quantification of P species for ^{31}P NMR spectra

Signal areas of classes of P compounds were calculated by integration by combining the spectral area occupied by the class of compound and the total P concentrations in the corresponding NaOH-EDTA extract. The four diagnostic chemical regions were orthophosphate (6.2–5.3 ppm), orthophosphate monoester (5.3–2.6 ppm), orthophosphate diester (2.0 to -1.0 ppm) and pyrophosphate (-4.5 to -5.5 ppm).

Individual peaks in the orthophosphate and orthophosphate monoester region were quantified by spectral deconvolution. Each spectrum was fitted with up to 15 sharp peaks (aromatic diesters, orthophosphate, α– and β–glycerophosphate, phytate, adenosine-5′-monosphosphate (AMP), *scyllo*-inositol phosphate and five unassigned peaks) and a broad base signal between 4 and 6 ppm.

Multiplying the relative intensity of the sharp peaks by the sum of the total extractable orthophosphate and monoester P concentrations gave the concentration of all P species in the soil. Phytate and orthophosphate concentrations were adjusted to account for the phytate C-2 peak which was obscured by the much larger orthophosphate peak. Total phytate concentration was calculated as 6/5 times the total concentration of the three observable resonances. Therefore, 1/5 of the total phytate concentration was subtracted from the total orthophosphate concentration.

Results

The assignment of the common peaks in each spectrum were identified by spiking known compounds into NaOH-EDTA extracts just prior to NMR analysis. Figure 1 shows the results of spiking experiments used to assign the resonances in the monoester region. It was clear that many of the peaks were common to most of the samples. These peaks included aromatic phosphate diesters, orthophosphate, α-glycerophosphate, phytate, β-glycerophosphate, AMP, *scyllo*-Inositol hexakisphosphate, orthophosphate diesters and pyrophosphate. All soils had an apparently low phytate concentration, which appears to contradict previous values determined using alternative methods.

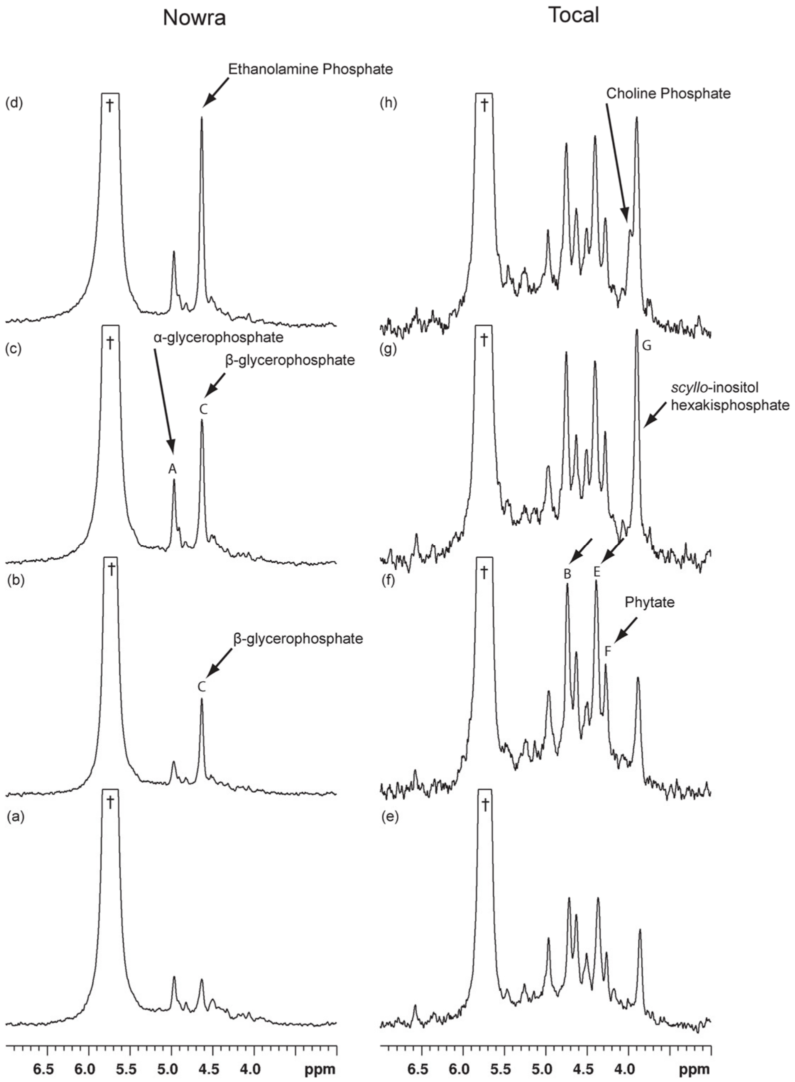

Figure 1. Solution ^{31}P nuclear magnetic resonance spectra of unspiked (a) Nowra and (e) Tocal NaOH–ethylenediaminetetraacetic acid (EDTA) soil extracts. The spectra show the consecutive addition of (b) β-glycerophosphate, (c) a 1:1 mixture of α- and β-glycerophosphate, and (d) ethanolamine phosphate to the Nowra NaOH–EDTA extract, and the consecutive addition of (f) phytate, (g) *scyllo*-inositol hexakisphosphate, and (h) choline phosphate to the Tocal NaOH–EDTA extract. Resonances A through G correspond to each of the peaks identified in the 18 soils. † Orthophosphate resonances. (reproduced (Doolette *et al.* 2009))

A large portion of organic P in the soil analysed was associated with a broad base signal between approx. 4 and 6 ppm. This complicates the deconvolution procedure and therefore the quantification of the spectra. This broad signal was present in all of the spectra, but was more easily discerned in the spectra which contained less intense monoester resonances. This broad base signal is overlooked in many other ^{31}P NMR spectra but has been identified in a few natural soils (Bünemann *et al.* 2008; Dougherty *et al.* 2007; Smernik and Dougherty 2007) but as observed by Bünemann *et al* (2008) and shown in Figure 2, is not observed in model soils that do not contain humified organic matter. It has been suggested that this broad feature may be due to large complexed forms of monoester-P in a wide range of only slightly different chemical environments, as opposed to smaller specific monoester-P compounds that form the sharp resonances (Dougherty *et al.* 2007).

Furthermore, it has been noted previously that failing to account for the broad signal can result in over-estimation of signal in the sharp resonances (Smernik and Dougherty 2007). Therefore, in providing a quantitative assessment of P in Australian soils it was vital to account for the presence of the broad signal in the monoester region, although it means a large portion of organic P cannot be assigned to specific molecules. This may also explain the surprisingly low phytate concentrations reported here, i.e. P which would have normally been assigned to phytate was assigned to the broad base signal.

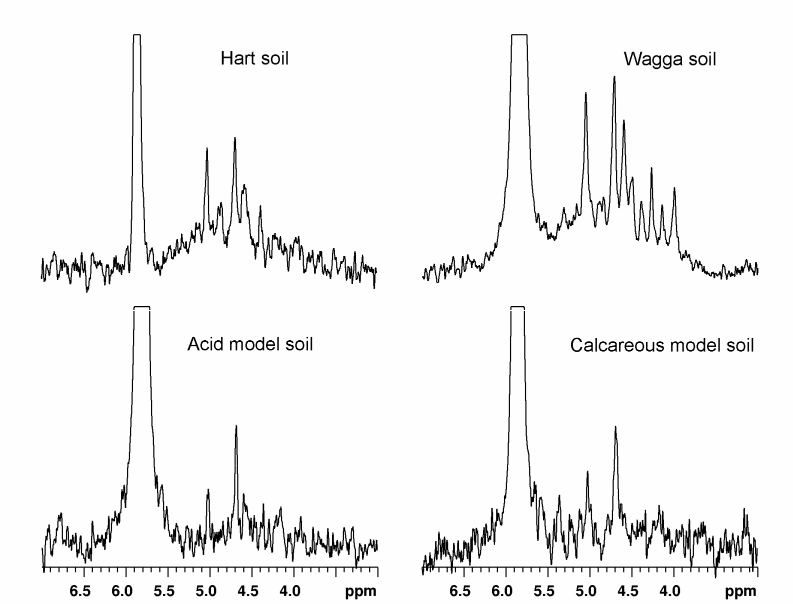

Figure 2. (Modified from Bünemann *et al* (2008)) solution ^{31}P NMR spectra of NaOH-EDTA extracts of a calcareous (Hart), acidic (Wagga) and acidic and calcarous model soil following a 25-week incubation with cellulose addition.

Conclusions

We have used an improved method for the speciation of soil P using solution ^{31}P NMR spectroscopy and spectral deconvolution. We showed that unless a broad, underlying signal in the orthophosphate monoester region is properly accounted for, the concentrations of other orthophosphate monoesters are likely to be inaccurately quantified. This broad signal represents a large portion of organic P, which we believe is P in large "humified" molecules. These findings have consequences for the way in which P cycling is currently viewed.

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Application of fuzzy logic to land suitability for irrigated wheat

P. Maleki[A], A. Landi[A], Gh. Sayyad[A], J. Baninemeh[B], Gh. Zareian[C]

[A]Shahid Chamran Universtiy of Ahvaz, Email maleki_1434@yahoo.com, foahmad@yahoo.ca, gsayyad@gmail.com
[B]Agricultural Research Center of Khuzestan, Email jamal_nn@yahoo.com
[C]Agricultural Research Center of Fars, Email zareian48@yahoo.com

Abstract
This paper aims to determine the quantitative impact of land qualities on irrigated wheat production, using fuzzy set (FS) theory. This theory was applied and compared with conventional Parametric-Storie (PS) method in a land suitability assessment for irrigated wheat production for two different regions, one in Sardasht-Behbahan area of Khuzestan province, southwest Iran, and the other in Neiriz-plain area of Fars province, south Iran.

The two methods performances was evaluated by comparing the relationships between observed yields and calculated land indices. Results showed that, for both regions, land suitability indices produced by FS method showed higher correlation with observed yields than those produced by conventional PS method. The coefficient of determination (R^2) between land suitability indices and observed irrigated wheat yield using FS and PS methods were in Sardasht-Behbahan 0.89 and 0.84, respectively. The same result, but with the sharp difference between two methods, were obtained in Neiriz-Fars-plain using FS (R^2=0.80) compared to PS method (R^2=0.34). Therefore, it can be calculated that even in situations where conventional methods can not well estimate crop yield, fuzzy method can improve the quality of land suitability assessment.

Key Words
Fuzzy logic, irrigated wheat

Introduction
Land evaluation is carried out to estimate the suitability of land for the specific use such as arable farming or irrigated agriculture. Land evaluation can be carried out on the basis of biophysical parameters and/or socioeconomic conditions of an area. Biophysical factors tend to remain stable, unlike socioeconomic factors that are affected by social, economic and political settings. Thus physical land suitability evaluation is a prerequisite for land-use planning and development. The accuracy of agricultural land evaluation depends on the significance of the chosen land qualities, with respect to their effects on crop production. Several procedures for estimating the impact of land qualities on crop production were established by field scientists, on the basis of reasoned intuition. A well-known, simple approach attributes a factor to each land quality that reduces the expected yield by a certain fraction. Example of this approach is "the Sys parametric approach".

It is realized that this conventional method fails to incorporate the fuzzy nature of much land resource data. Other disadvantages are: arbitrary selection of land qualities, poor definition of land productivity factors, experience-dependent decisions and spurious precision of results. Another new method is fuzzy logic which determines the quantitative impact of land qualities on land suitability so that a value of outside a specified range can be minimized. The Fuzzy method differs from the conventional land evaluation procedures by (1) the use of an explicit weight for the effect of each land quality on crop performance and (2) the way of combining the evaluation of land qualities into a final land suitability class or land suitability index. Soil condition can affect the result of land suitability assessment. This study was conducted to compare the performances of two Land evaluation methods, conventional (the Parametric-Stori approach: PS) vs. Land evaluation using Fuzzy set (FS) method, for irrigated wheat production in two different regions. The selected regions have different soil and climate conditions and are located in the southeast (Sardasht-Behbahan) and the south (Neiriz-plain-Fars) of Iran.

Materials and methods
Materials
Two regions were selected for the study. The first region (Sardash) covers approximately 6000 hectares and is located in the southeastern part of the Behbahan, Iran, between 30˚ 28´ to 30˚ 27´ NW and 50˚ 2´ to 50˚ 17´ WL. A total of 14 representative soil units from this region were considered for this study. Most of the soils belonged to the order of Inceptisols, and some were classified as Entisols. Based on eleven years

meteorological data (1993-2003), the mean monthly air temperature ranged from 6.9°C to 28.3°C, and the mean annual rainfall was 340.8 mm. The other study region, Neiriz-plain is located at 15 KM south of Shiraz between 54˚ to 54˚ 25´WL and 29˚8´ to 29˚ 27´ NW.A total of 10 representative soil units from the studied area were considered. Most of this soils belonged to the order of Inceptisols. Based on 15 years meteorological data (1991-2006), the mean monthly temperature ranged from 43°C to -8°C, and the mean annual rainfall was 204 mm.

Methods

Parametric approach

In the parametric approaches, all individual land quality rating values are multiplied to produce one numerical index. According to the Storie method (Storie 1976), the land index is the product of the individual rating values of all land qualities, using the following formula:

$$LI = \left(\prod_{j=1}^{n} R_J \right) .100$$

Where LI is the land index, n is the number of land qualities and R_j is the rating value of the jth quality.

Fuzzy set approach

The Fuzzy set theory (Zadeh 1965) is a body of concepts and a technique that gives a form of mathematical precision to human thought processes that are imprecise and ambiguous in manu ways. The application of the fuzzy set theory to determine the impact of land qualities irrigated wheat production comprises several steps:

- Detemination of membership functions
- Determination of membership values
- Determination of reference weight and reference suitability matrices
- Determination of weight values for different land qualities

In this study the membership function was defined as Kandel extention membership function as follows:

$$MF = \frac{1}{\left\{ 1 + \left(\frac{Z(x) - b1 - d1}{d1} \right) \right\}} \qquad \text{If } Z(x) < b_1 + d_1$$

$$MF = 1 \qquad \text{If } b_1 + d_1 \le Z(x) \le b_2 - d_2$$

$$MF = \frac{1}{\left\{ 1 + \left(\frac{Z(x) - b2 + d2}{d1} \right) \right\}} \qquad Z(x) > b_2 - d_2$$

In this function $b_1$and b_2 are lower and upper limits, and d_1 and d_2 are the width of transition regions. As the effect of each land attribute on wheat yield was different, the weight of each land attribute was calculated using multiple regression between observed yield and land attributes.

Results and discussion

The observed wheat yields and produced land indices using FS and PS methods for each land unit are given in table 1. The average irrigated wheat yields in the Sardasht-Behbahan and Neiriz-Fars were 3518±1684 and 3550±2321 kg ha^{-1}, respectively. For both regions, the produced FS indices for each land unit were more than those produced by PS method. The relationship between land indices obtained by the different methods and the observed yields are given in Figure 1. For both regions, land suitability indices produced by FS method showed more relationship with observed yields than those produced by conventional PS method. The coefficient of determination (R^2) between land suitability indices and observed irrigated wheat yield using FS and PS methods were in Sardasht-Behbahan 0.89 and 0.84, respectively. The same result, but with the sharp difference between two methods, were obtained in Neiriz-Fars-plain using FS (R^2=0.80) compared to PS method (R^2=0.34). Our results shows that even in regions where conventional PS method can not well estimate crop yield, fuzzy method can improve the quality of land suitability assessment. Although our results show the comparative advantages of FS than PS method, however the obtained correlation in FS method was still far of desired "one". Possibly because crop yield is not only dependents on land indexes but other factors like farm management is very important in this way and should be included in the land evaluation.

Table 1. Observed irrigated wheat yields and calculated land indices for the different land units in Sardasht-Behbahan(a) and in Neiriz-Fars-plain (b).

(a)

Land unit	Observed yield (kg/ha)	land index	
		Parametric method	Fuzzy method
1.1	3372	60.400	79.67
2.1	4300	72.400	80.60
2.2	5200	66.400	82.59
2.3	4720	75.400	78.30
2.4	3050	59.300	79.62
2.5	0	18.600	49.65
3.1	4200	65.900	79.54
4.1	5100	72.200	81.27
4.2	3965	76.400	80.39
4.3	4166	66.600	79.80
5.1	4530	55.900	81.18
5.2	2254	35.900	63.35
5.3	4400	76.400	81.64
5.4	0	27.200	54.32

(b)

Land unit	Observed yield (kg/ha)	land index	
		Parametric method	Fuzzy method
1.1	5200	59.2	71.62
1.2	5000	59.5	74.74
1.3	4500	38.9	76.27
2.1	7000	78.6	77.03
2.2	6500	70.2	73.03
3.1	1500	59.1	61.21
3.2	1800	58.8	61.89
3.3	1500	49.8	59
3.4	1500	57	61.89
3.5	1000	27.7	49.08

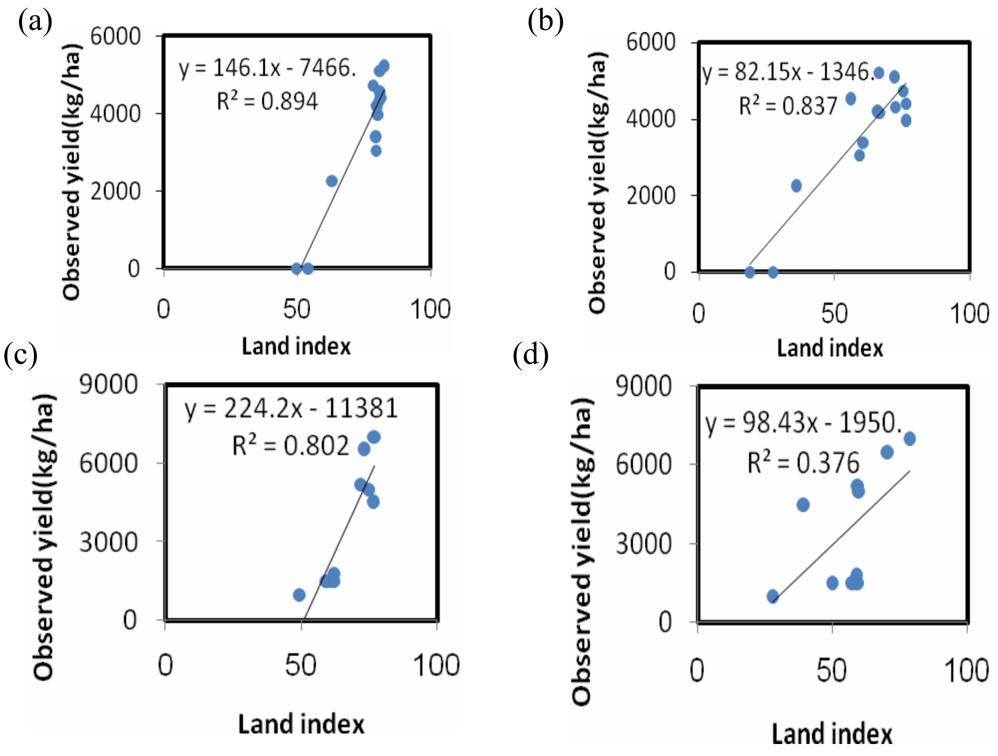

Figure 1. Linear regrression between the land indices and observed irrigated wheat yields in Sardasht-Behbahan obtained with (a) the fuzzy set, (b) the parametric methods and in Neiriz-Fars-plain using, (c) the fuzzy set and (d) the parametric methods.

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Application of MCDM method in Fuzzy Modeling of Land Suitability Evaluation

Fereydoon Sarmadian[A] , Ali Keshavarzi[A] , Behnam Rajabpour[A] , Sadegh Askari[A]

[A]Department of Soil Science,Faculty of Soil and Water Engineering, University of Tehran, Karaj, Iran
Email: fsarmad@ut.ac.ir, aliagric@gmail.com

Abstract
Classical and conventional (traditional) land suitability methods are based on Boolean's Two-valued Logic that defines different land suitability classes completely distinctive. These methods have many disadvantageous in description of capabilities and land suitability for different applications, therefore fuzzy modeling based on fuzzy sets theory is the best method in land suitability assessment. In this theory, membership is not two-valued; instead it could be a range of values from 0 to 1. The function that states the degree of membership in a set is named "membership function". In this research, Pairwise Comparison Method in the form of Analytical Hierarchy Process(AHP) used for weighting different assessed criteria for land suitability of an irrigated wheat field in Takestan and results from fuzzy methods compared with those from conventional methods, for example Parametric method. The correlation coefficient between land index and observed yield in the study area were 0.91 and 0.85 for the fuzzy approach with AHP method and parametric approach respectively.

Key Words
Two-value logic(classic logic); Fuzzy sets theory; Irrigated wheat; Analytical Hierarchy Process(AHP); Takestan.

Introduction

In general, land suitability describes "the fitness of a given parcel of land for specific uses" (FAO 1976).Appropriate land use decisions are vital to achieve optimum productivity of the land and to ensure environmental sustainability. This requires an effective management of land information on which such decisions should be based. Land suitability evaluation is one of the effective tools for such purposes.(baja *et al*. 2001). There are generally two kinds of land suitability assessment approaches. First, the qualitative approach is used to assess land potential at a broad scale or is employed as a preliminary method for more detailed investigation (Baja *et al*. 2002; Dent and Young 1981). The results of qualitative classification are given in qualitative terms, such as highly suitable, moderately suitable, and not suitable. The qualitative factors could not use the numerical score to present. Second, the quantitative approach is using parametric techniques involving more detailed land attributes which allow various statistic analyses to be performed (Baja *et al*. 2002; 2001). Quantitative methods such as modeling in land evaluation are necessary for a land use planning (Van Diepen *et al*. 1991). Recently, most studies combined the qualitative and quantitative approaches in the process of land suitability assessment.One of the most recently used models in land evaluation is fuzzy model. In the real world, some objects are quite differentiated from others and their boundaries are quire evident: a river crossing through a valley is quite distinguishable from its surroundings when in full discharge, an area covered by a lake is distinct from the land areas surrounding it; but soil and vegetation and other patterns in nature change transitionally: the limit between two types of soil or vegetation is, in most of the cases, not so clearly defined. Fuzzy modeling appears as an alternative to deal with these continuous or uncertain environments. While in Boolean logic a value is true of false, with fuzzy logic the value could be partially false of partially true which allows for a representation more according to the reality. Hierarchy Process (AHP) as proposed by Thomas Saaty in the early 1980s.AHP can be used as a consensus building tool in situations involving a committee or group decision-making (Saaty 1980). AHP uses a hierarchy of factors where each general factor is subdivided or composed of several contributing subfactors.The objective of this study is to apply fuzzy set technique for land suitability evaluation and relate it to irrigared wheat yield in Takestan area. Yield information is of interest to users (farmers) and policy makers (government officials) who are responsible for rural development

Methods

The Study Area

The land investigated in research located in Takestan(Qazvin province) and has the area of 40000 hectares;

between latitudes of 36°3´33´´ and 36°14´14´´ N and between longitudes of 49°32´45´´ and 49°53´51´´ E at north of Takestan city. The average, minimum and maximum heights are 1668, 1216 and 2119 meters from sea level respectively. Figure1, shows the study area in Qazvin province and Iran.

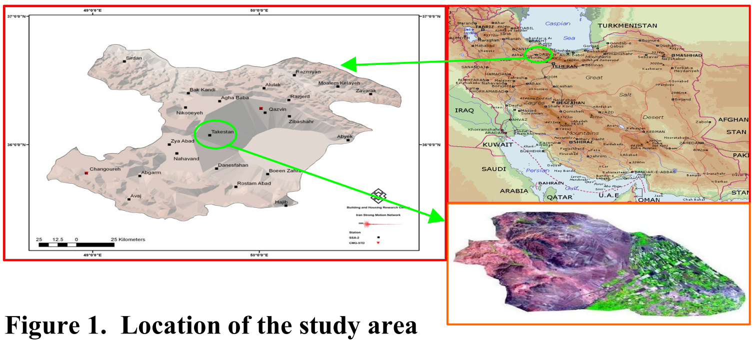

Figure 1. Location of the study area

In this study, the 1:25000 scale topographic lines were studies to prepare elevation model and the soil map of region was generated via digital elevation model, slope map, geological map and field and experimental studies(Figure 2). The studied region has two soil temperature regimes, Thermic and Mesic which the Thermic regime mainly covers eastern sections and Mesic regime includes western section. Furthermore, the studied area has two soil moisture regimes including Aridic and Xeric regimes.

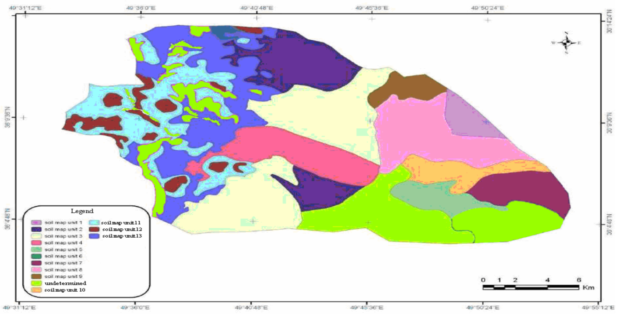

Figure 2. soil map units of the study area

Based on Soil Taxonomy(2006), this region has soils in Entisols,Aridisols and Inceptisols orders. Using GPS device and base map, profiles location defined and profiles excavated and described using presented methods in “Field Book Describing and Sampling Soils”(1998).

Application of fuzzy set theory in land suitability evaluation

The studied area was divided into 13 land units and 8 land characteristics that are effective in irrigated wheat selected including slope (%), soil depth (cm) cation exchange capacity (Cmol+/kg), electrical conductivity (dSm^{-1}) Sodium adsorption Ratio, volumetric content of gravel (%), organic carbon content in soil (%) and Calcium carbonate content (%). The irrigated wheat requirements were determined using FAO frame work for land evaluation (Sys 1985). In the studied region plain lands has gentle slope and mountain land has steep slope. To determine the land suitability classes for irrigated wheat via land biophysical characteristics, the Fuzzy and Classic methods used. In classic method (parametric), first a degree designated to each limitation levels, then based on intensity limitation relevant degree determined for each land characteristic and via Storie method, land index in each land unit obtained and finally land suitability class determined. In fuzzy method based on irrigated wheat requirements the Sigmoidal(Tang *et al*. 1992) and Kendel membership functions were used to determine degree of membership for each land characteristic to land suitability classes and the results were set in a matrix named characteristic matrix(R). Then, via Analytic Hierarchy Process the weight of each effective land characteristic in irrigated wheat cultivation was calculated and put in weights matrix (W). The Analytic Hierarchy Process is based on pair-wise comparisons for generation of relative matrix. In this method, pair-wise comparisons considered as input and relative weights are as outputs. The Saaty scale (1980) was used for generation of pair-wise comparison matrixes which relatively rates priorities for two criteria. The criteria priorities are defined according to expert’s comments and experience. After generation of pair-wise comparisons matrix, the criteria weights are calculated that includes sum of each column of pair-wise comparison matrix and division of each component by the result of each relevant column sum. The resulted matrix is knows as normalized pair-wise comparison matrix. The average of each row of the pair-wise comparison matrix is calculated and these average values indicate relative weights of compared criteria.To determine the final land suitability class in each land unit, a multiple operator (combination) used and characteristic matrix in each land unit (R) multiplied by weights matrix (W) and resulted final matrix of land suitability (E). Components of land suitability matrix indicate degree of membership of relevant land unit to land suitability classes. This matrix is calculated as: $E = W \circ R$. in order to calculate land index, the sum of components of land suitability matrix (E) is set to one (standardized) and the new components of matrix are multiplied by average of indexes of land suitability classes respectively.

Results

As indicated in Table1, land suitability evaluation via fuzzy method increased land indices in some land units and improved some land suitability classes.The calculated regression between land index and region production (Figure 3), was 0.91 and 0.85 for fuzzy sets theory and parametric method respectively.A comparison between results of this research and other investigators as well as (Tang *et al*. 1992; Van Ranst *et al*. 1996) indicates that the fuzzy method with higher correlation factor, has more accuracy and capability of predicting production, since fuzzy set method considers continual land changes and is more efficient in reflecting spatial variability of soil characteristic rather than Bool's two-valued logic that overlooks a considerable section of useful information during land evaluation processing. Nonetheless, accuracy of results is mainly dependant on designated weights to different land characteristics.Although in land suitability evaluation, nowadays the emphasis is on quantitative (numerical) methods, but of fuzzy sets theory's problem in land suitability evaluation is the high volume of calculations. On the other hand, increase in the number of land characteristic increases the number of pair-wise comparisons in comparison matrix and decision making on spatial variability of different characteristics in each land unit becomes difficult because different characteristics has different weights and weight designation to characteristics needs more experience and criteria precedence.

Table1 .Observed irrigated wheat yield , land suitability classes and land indices obtained by different methods for the different land units in Takestan area

Land unit No.	Observed yield (kg/ha)	Land suitability evaluation for irrigated wheat by different methods	
		parametric approach class (index)	fuzzy approach class (index)
1	4799.5	***S1*** (86)	***S1*** (90)
2	3569.4	***S2*** (81)	***S2*** (84)
3	3381.6	***S2*** (67)	***S2*** (82)
4	2642.5	***S2*** (65)	***S2*** (77)
5	3406.4	***S2*** (70)	***S2*** (76)
6	2382.8	***S3*** (59)	***S2*** (73)
7	2220.0	***S3*** (57)	***S2*** (72)
8	4778.9	***S1*** (86)	***S1*** (90)
9	3823.1	***S2*** (82)	***S2*** (80)
10	2222.7	***S3*** (57)	***S2*** (73)
11	2358.7	***S3*** (58)	***S2*** (65)
12	4801.1	***S1*** (86)	***S1*** (87)
13	3168.7	***S3*** (46)	***S2*** (80)

Conclusion

Fuzzy logic is an attempt to extend the concept of continuous variation of soil properties from the geographic space to the attribute space (Burrough *et al*. 1997). Boolean logic works on the principle that a site can belong to one and only one suitability class (e.g., suitable or not suitable). In reality however, there is usually an overlap of classes in the attribute space. The admission of the idea of partial overlap of classes is expressed in terms of membership functions using fuzzy logic.

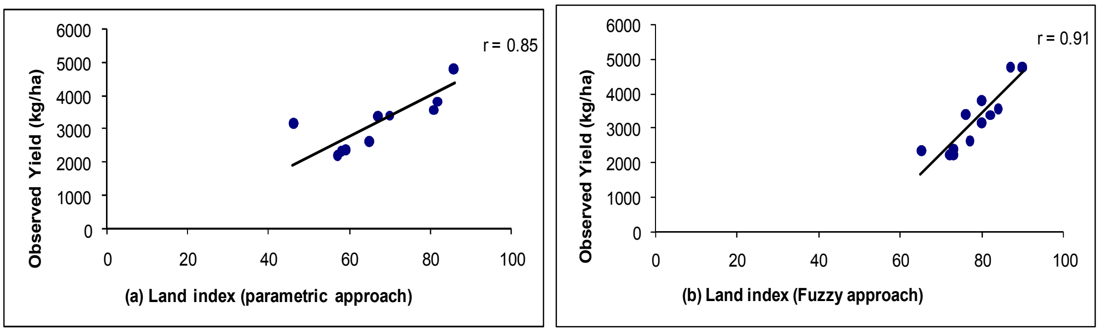

Figure 3. Linear regression between land suitability indices obtained with :(a) parametric approach and (b) fuzzy approach , and observed irrigated wheat yield in Takestan area

This approach was used by Lark and Bolam (1997) to address both uncertainty in prediction and uncertainty in interpretation of soil data for sugar beet production.The approach we present in this study does not incorporate management decision. Use of the land for wheat or any other crop remains a management decision. Similarly, the fact that an area has a relatively high suitability index does not automatically imply that high yields would be obtained if, for instance, the timing of planting or fertilizer application was wrong (braimoh *et al*. 2004). A major advantage of dynamic simulation models over the approach presented here is that dynamic simulation models can incorporate management decisions such as fertilizer application, time of planting, water application, and so forth in predicting crop yields. However, a major problem in utilizing such models in land evaluation is the requirement for large amounts of data. The use of fuzzy technique in this study produced land suitability for irrigated wheat in a continuous scale. Land suitability indices, reflecting inherent fertility of the soils(braimoh *et al*. 2004). High correlation between wheat yield and land suitability offers an explanation for the upward trend in wheat yields in the study area. Our approach is well applicable for applications in which subtle differences in soil quality are of a major interest. Using the SI model, we were able to evaluate the limitations of land characteristics to wheat in the study area. Major constraints to the use of fuzzy technique for land suitability evaluation thus proved valuable for identifying major constraints to crop production and strategies for overcoming them.

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Assessing agricultural soil quality on a global scale

Lothar Mueller[A], Uwe Schindler[A], T. Graham Shepherd[B], Bruce C. Ball[C], Elena Smolentseva[D], Chunsheng Hu[E], Volker Hennings[F], Peter Schad[G], Axel Behrendt[A], Katharina Helming[A] and Frank Eulenstein[A]

[A] Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) Müncheberg, Eberswalder Straße 84, D-15374 Müncheberg, Germany, Email lmueller@zalf.de
[B] BioAgriNomics Ltd., 6 Parata Street, Palmerston North 4410, New Zealand, Email G.Shepherd@BioAgriNomics.com
[C] Crop and Soil Systems Research Group, SAC, West Mains Road, Edinburgh EH9 3JG, UK, Email Bruce.Ball@sac.ac.uk
[D] Russische Akademie der Wissenschaften, Institut für Bodenkunde und Agrochemie (ISSA), Sovetskaya 18, Novosibirsk 630099, Russia, Email smolentseva@issa.nsc.ru
[E] Center for Agricultural Resources Research Shijiazhuang, China, Email cshu@sjziam.ac.cn
[F] Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) Geozentrum Hannover, Stilleweg 2, D-30655 Hannover, Germany, Email Volker.Hennings@bgr.de
[G] Wissenschaftszentrum Weihenstephan, TU München, Freising, Germany, Email schad@wzw.tum.de

Abstract
Food insecurity due to limited and degraded soil resources is a threat of the 21st century. The aim of the paper is to analyse potentials and deficiencies of current approaches for assessing agricultural soil quality consistently over a range of spatial scales. The analysis includes both the description of methods of soil quality evaluation and results of field tests across Eurasia. We found that the soil moisture and thermal regime are the main constraints to the soil productivity potential on a global scale. However, most taxonomic soil classification systems provide insufficient information on soil functionality. Visual soil assessment methods have been developed as diagnostic tools for the recognition and evaluation of the morphological and functional status of soil. They offer the potential for use in extension, monitoring and modelling the management-induced changes of agricultural soil quality. A straightforward overall soil functional assessment framework based on soil indicators may explain most of crop yield variability of cereals. Such a system which includes the soil thermal and water regime and management induced and inherent aspects of agricultural soil quality is the Muencheberg Soil Quality Rating. This system could serve as a functional supplement to the World Reference Base for Soil Resources, ranking and controlling agricultural soil quality on a global scale.

Key Words
Soil quality, indicator, crop yield, visual soil assessment, Muencheberg Soil Quality Rating

Introduction
The function of soils to provide food, fibre, and further essential goods for humans is closely associated with the main global issues of the 21st century like food security, demands of energy and water, carbon balance and climate change (Lal 2009). A growing global community of land users and stakeholders seeking to achieve high soil productivity in the context of a sustainable multifunctional use of soils and landscapes will demand assessment tools for agricultural land worldwide. A crucial question arises: Are adequate operational tools available to assess the functional status of the agricultural soil resource consistently over spatial scales? The aim of the study was to detect potentials, deficiencies and gaps in knowledge of current approaches for assessing soil quality and the productivity potential of soils. Conclusions for further work on assessing and evaluating the functional status of the soil resource should be drawn.

Methods
We analysed available methods for assessing soil quality and its productivity potential by different criteria like field method suitability, performance and crop yield relevance over different scales. Field analyses were performed to test the visual soil assessment methods of Shepherd (2000), Ball *et al*. (2007). Different soil profiles were also analysed in agricultural landscapes of Eurasia. Soils were classified according to the World Reference Base for Soil Resources (WRB 2006) and functionally assessed by the Muencheberg Soil Quality Rating (M-SQR, Mueller *et al.* 2007). Field soil data were surveyed according to FAO (2006) guidelines for soil description. Crop yields and management intensity data were taken from agricultural research reports.
The New Zealand Visual Soil Assessment (VSA) method (Shepherd 2000) is a multi-parameter technique based on scoring of soil by different criteria. Measuring the disaggregation of soil after a drop-shatter test is the key criterion for assessing soil structure and helps minimise the subjective handling of the soil prior to assessment. The Muencheberg Soil Quality Rating (M-SQR, Mueller *et al.* 2007) has been developed as a

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potential international reference base for a functional assessment and classification of soils (Figure 1). It focuses on cropland and grassland and is based on productivity-relevant indicator ratings which provide a functional coding of soils. Two types of indicator are identified. The first are basic and relate mainly to soil textural and structural properties relevant to plant growth. The second are hazard-based, relating to severe restrictions of soil function. The sum of weighted basic indicator ratings and ratings of the most severe (active) hazard indicator, yield an overall soil quality rating index. Indicator ratings are based on a field manual and utilize soil survey classifications (FAO 2006), soil structure diagnosis, and local or regional climate data.

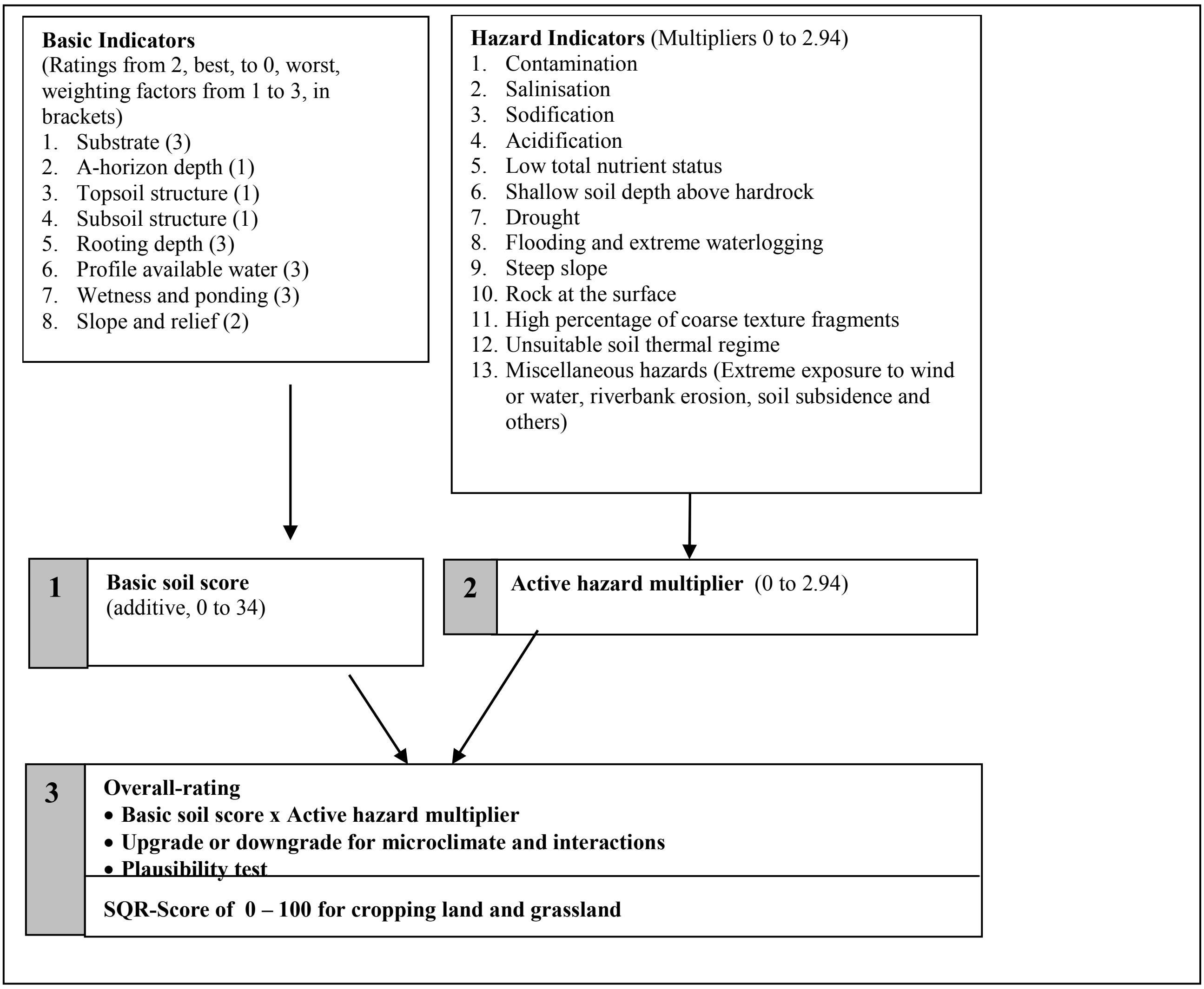

Figure 1. Indicator system of the Muencheberg Soil Quality Rating (Mueller *et al.* 2007).

Results

The performance of visual soil assessment methods

Visual soil assessment methods define macro-morphological features of soil structure that can be detected and evaluated in the field. Soil structure is a criterion of agricultural soil quality. It is particularly vulnerable to change by management and degradation processes like compaction and erosion, and its preservation is key to sustaining soil function. Soil structural features meet the farmers perception of soil quality (Shepherd 2000; Batey and Mc Kenzie 2006) and are correlated with measured data of physical soil quality and crop yield (Mueller *et al.* 2009). Visual assessment of soil structure may serve as a diagnostic tool for the recognition and evaluation of the morphological and functional status of soil. This offers semi-quantitative information for use in extension and monitoring or even modelling (Roger-Estrade *et al.* 2009). Over the past decades, several methods have been evolved. One of the most accepted methods is that of Peerlkamp (1967). It has a conjoint scale referring to type and size of aggregates and pores. The main advantages of this method are speed and minor soil disturbance, providing comparative statistical analyses both in large fields and also in small plots of long-term trials. However, the scoring framework has potential for subjective errors. In a study relating soils data derivable from visual scoring to crop growth, types and sizes of aggregates and abundance of biological macropores were the most reliable criteria relating to measurement data. In addition, differences in soil management or effects of compaction may be detected by visual assessment of the soil (Batey and McKenzie 2006; Mueller *et al.* 2009). In the same study, unfavourable visual structure scores were associated with increased dry bulk density, higher soil strength and lower infiltration rate, but correlations were site-specific (reference required). Visual soil structure assessments may thus form an important part of overall soil characterizations (FAO 2006; WRB 2006, Mueller *et al.* 2007). Visual methods based on, or supplemented by illustrations, have clear advantages for the reliable assignment of a rating score based on visual diagnostic criteria. Illustrated methods like the updated Peerlkamp method (Ball *et al.* 2007) and the Visual Soil Assessment (Shepherd 2009) are particularly effective and reliable to apply.

Comparison of some methods of assessment of overall soil quality

Specific soil and land evaluation schemes exist on a national basis. Their soil data inputs differ, evaluation ratings are not transferable and not applicable in international studies. From current available overall soil assessment schemes, the multi-indicator based Canadian Land Suitability Rating System (LSRS, Agronomic Interpretations Working Group 1995) and the Muencheberg Soil Quality Rating (M-SQR, Mueller *et al.* 2007) meet best the criteria for a worldwide comparison of overall soil quality and productivity potentials for cropping cereal-dominated rotations. They should be tested and compared, and evolved towards a functional supplement to the World Reference Base for Soil Resources.

Relevance of soil quality assessment methods for crop yield

Visual soil structure assessment may explain only part of crop yield variability, as the influence of inherent soil properties and climate on crop yield is dominant, particularly over larger regions. Attributes of the WRB 2006 database attributes such as reference soil groups and texture qualifiers may thus provide important information on the yield of cereals and grass. However, if the classes of oil thermal and moisture regimes are not taken into consideration, less than 50% of the crop yield variability in the supra-regional scale can be explained by WRB reference soil groups and qualifiers only (Table 1).

Table 1. Coefficient of determination (B) of multiple regressions between grain yield of cereals and soil parameters.

Reference soil groups (RSG) and land use	Variant of classification	B
All RSG, high-input farming (n=352)	1) Soil attributes only (Qualifiers of WRB 2006)	0,20**
	2) Soil attributes and thermal and moisture regime	0,61***
	3) M-SQR-score (Muencheberg Soil Quality Rating)	0,78***
Phaeozems, Chernozems und Kastanozems, high-input farming (n=54)	1) Soil attributes only (Qualifiers of WRB 2006)	0,00
	2) Soil attributes and thermal and moisture regime	0,65***
	3) M-SQR-score (Muencheberg Soil Quality Rating)	0,74***
All RSG, organic and low-input farming (n=43)	1) Soil attributes only (Qualifiers of WRB 2006)	0,36**
	2) Soil attributes and thermal and moisture regime	0,63***
	3) M-SQR-score (Muencheberg Soil Quality Rating)	0,87***

Soil moisture and thermal regimes which are climate-controlled are, like pedogenesis, the main constraints to potential soil productivity on a global scale. However, most taxonomic soil classification systems, including the World Reference Basis for Soil Resources, and even many national soil rating frameworks, provide insufficient information on soil functionality, including the productivity function on that scale. Figure 2 shows clear differences in crop yield between soils of mesic and frigid to cryic temperature regimes. Within the mesic temperature regime, sandy soils (Arenosols) have a significantly lower crop yield potential. Overall soil quality rating systems which include information on climate, textural and structural properties, may explain between 70 and 87% of the crop yield variability (Table 1).

Conclusion

The Muencheberg Soil Quality Rating has potential as a reference method of rating potentials and limitations of soils for cropping and pastoral grazing at different scales. It can serve as a crop yield estimator for cereals on a global scale. Regarding assessing agricultural soil quality and the productivity function of soils, it could also be a useful supplement to the WRB 2006 soil classification.

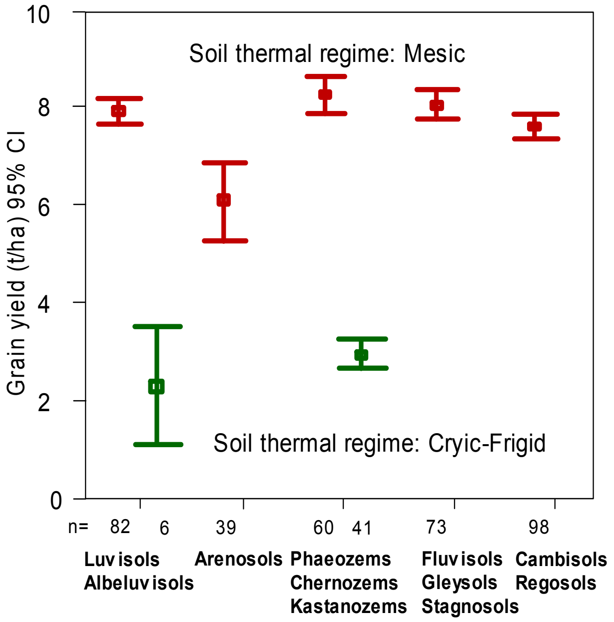

Figure 2. Grain yields of cereals in Eurasia stratified by soil thermal regimes and Reference Soil Groups of the WRB 2006. Sites are mainly located in Germany, western Siberia and northern China. Cereals are wheat, rye, oats or barley, whichever had the highest local crop yield.

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Before and after: the make-up of native and disturbed mine soil materials.

Katharine Brown and Robert Gilkes

School of Earth and Environment, The University of Western Australia, Crawley, WA, Australia. Email: klbrown@see.uwa.edu.au

Abstract

The bulk-handling of native soil materials during mining operations may contribute to an increase in soil strength (hardsetting) in minesoils. The penetration resistance (PR) of soil materials from a mineral sands mine was measured to assess whether disturbance of these materials affected soil strength. The penetration resistance curve was empirically characterised using 6 parameters from which summary curve parameters were derived. There were clear relationships between the summary curve parameters Average Force (N) and Maximum Strength (N), and VWC % for individual mine soil materials. The mine soil materials that are high in clay are stronger and strength is more sensitive to water content. Interpretation of thin sections of native and disturbed mine soil materials, and the quantification of their fabric descriptions in ImageJ, indicated that physical disturbance changed the fabric of the native soil materials. The parameters that best identify variations in soil fabric were established from principal component analysis of the measured soil properties and the ImageJ parameters. These results have implications for the management of mine soil materials and encourage specific handling of soil materials based on their clay content.

Keywords

Minesoils, hardsetting, penetration resistance, soil fabric, ImageJ, principal component analysis.

Introduction

The appropriate management of mine soil materials is a key component of successful landscape reconstruction and the proper placement of soil or unconsolidated material should result in the development of a stable soil structure (Toy and Black 2000). The bulk-handling of native soil materials during mining operations tends to destroy soil structure and can lead to an increase in soil strength (hardsetting) in the newly constructed soils (minesoils) of a reconstructed landscape. While the relationships between hardsetting, soil strength and soil moisture are well documented (Mullins and Panayiotopoulos 1984; Harper and Gilkes 1994), the effects of disturbance during land rehabilitation on these soil properties are not clearly understood. In this research we measured the penetration resistance of soil materials from a mineral sands mine to assess whether disturbance of these materials affected soil strength.

Methods

The mine soil materials

We collected eight mine soil materials representing the native, constructed and overburden soil materials of a mineral sands mine located on the Swan Coastal Plain in south-west Western Australia. A further two materials, tailings sands and clay slimes, were also examined. These are by-products of the mineral extraction process and are often used in post-mining landscape reconstruction. The properties of each mine soil material were described using methods specified in McDonald *et al.* (1998) and Rayment and Higginson (1992).

Sample preparation

The mine soil materials were packed into plastic rings to an approximate dry bulk density of 1.6 g/cm^3 and placed on a Whatman Grade No. 5 filter paper. The samples were placed on a dry kiln tile in a wetting tray for slow wetting by capillary action. When the samples showed free water on their surface for a period of 24 hours, they were weighed and transferred to ceramic plates previously saturated with degassed, deionised water for equilibration at -10, -33, -300, or 1500 kN/m^2. Once the samples had equilibrated they were removed from the plate and weighed immediately prior to measuring the penetration resistance.

Measuring penetration resistance (PR)

The PR (strength) of each sample was measured using a Basic Force Gauge (BFG) fitted with a 6mm flat-end probe. The BFG does not have the capacity to measure sleeve friction so the PR is the total resistance, including sleeve friction, during penetration (Liu *et al.* 2006). The BFG was attached to a Mecmesin UltraTest Stand and, in single cycle mode, the penetration velocity was controlled at 12.5 mm/ hr. A graph of the resistance to the advancing probe over time was plotted using Dataplot™ software (Figure 1).

Image analysis
Thin sections of the mine soil materials were examined under an optical microscope with plain and polarised light. Optical micrographs (OM) and scanning electron micrographs (SEM) were obtained from each thin section (Figure 2). The fabric of each sample was described using a flow chart for OM description of soils adapted from Bullock *et al*. (1985) and the fabric descriptions were quantified in ImageJ, a public domain Java image processing program (Rasband 1997-2009). The OM and SEM images were edited, analysed and processed prior to applying the standard algorithms for analysing particles.

Statistical analysis
Statistical summaries for the quartz, clay matrix, organic material, heavy mineral and void fabric components were calculated prior to principal component analysis (PCA). The initial dataset consisted of five statistical measures (mean, median, standard deviation, skewness and kurtosis) of the seven particle, aggregate and void properties (area, perimeter, ellipse major, ellipse minor, ellipse angle, circularity and Feret's diameter). Due to the large number of variables (35), PCA was performed separately on each of the fabric components. Further analysis was then performed on a reduced dataset with all the fabric components.

Results

The properties of the mine soil materials

Table 1. The physical and chemical properties of the mine soil materials.

Soil material	Sand %	Silt %	Clay %	Bulk density	pH ($CaCl_2$)	EC (mS/m)	Exch. Cations Ca	Mg	Na	K	ECEC meq/100g	ESP	Total C %
Native Subsoil 1	85	1	14	1.6	6.6	14	0.2	0.1	0.0	0.0	0.4	8.3	0.0
Native Subsoil 2a	77	1	22	1.7	4.5	4.1	1.3	0.4	0.1	0.1	1.9	3.8	0.3
Native Subsoil 2b	71	1	28	2.0	4.4	2.3	0.6	0.3	0.1	0.0	0.9	5.3	0.1
Native Overburden	59	1	40	1.9	4.3	3.2	0.2	0.1	0.1	0.0	0.4	22	0.1
Constructed Subsoil 1a	88	1	11	1.6	5.7	11	1.6	0.5	0.1	0.1	2.2	2.2	0.2
Constructed Subsoil 1b	88	2	10	1.7	4.5	10	0.6	0.4	0.2	0.0	1.2	17	0.3
Stockpiled Subsoil 1a	84	1	14	1.8	5.3	31	1.2	0.9	0.6	0.1	2.8	21	0.3
Stockpiled Subsoil1b	75	1	24	1.8	5.7	3.9	1.0	0.2	0.1	0.1	1.3	4.5	0.3
Tailings sand	98	1	1.0	1.7	5.8	23	1.7	3.9	0.4	0.1	6.1	7.0	0.0
Clay slimes	18	1	81	NA	5.4	14	1.2	4.9	0.6	0.1	6.8	8.6	0.1

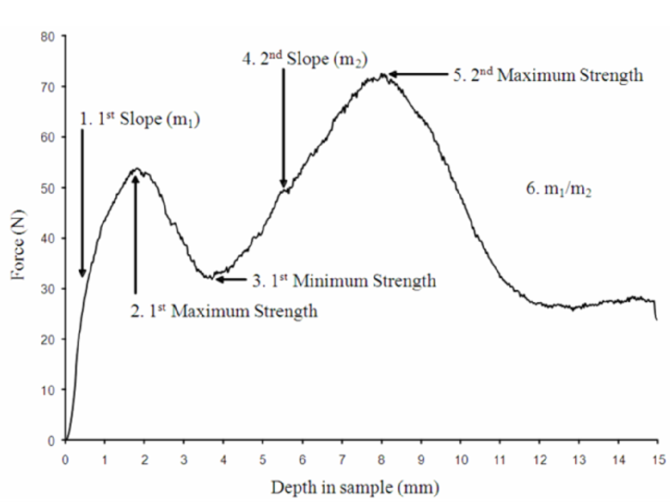

Figure 1. The resistance curve for Constructed Subsoil 1b and definitions of the 6 curve parameters.

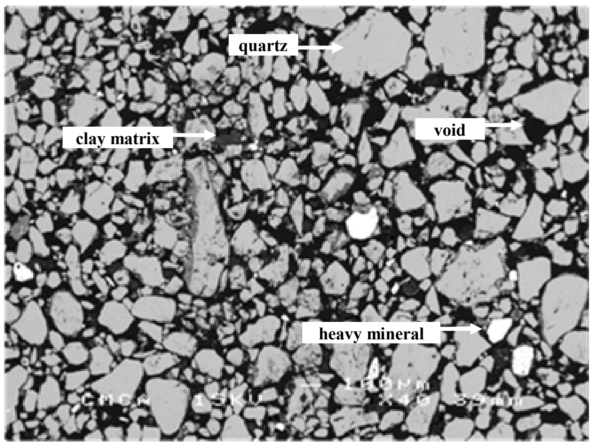

Figure 2. SEM of Constructed Subsoil 1b, identifying each of the fabric components.

Penetration resistance of the mine soil materials
A diverse range of resistance curves was observed for the mine soil materials. The curves were empirically characterised using 6 parameters (Figure 1) from which summary curve parameters were derived. Average force (AF) in Newtons (N) was chosen as the primary summary curve parameter because it is the average of

the maximum and minimum strength parameters, and it has a strong relationship with the maximum strength (MS) in Newtons (N) recorded for each sample) ($r^2 = 0.98$). A linear correlation matrix was generated to establish the relationships between the summary curve parameters and the sample properties of bulk density (BD g/cm^3), volumetric water content (VWC %) and clay (C %). Bivariate plots indicated that there are no clear associations across all samples between the resistance curve parameters and the sample properties for the normal or ln transformed data. There are, however, clear relationships between the summary curve parameters and VWC % for individual materials. Of these, AF and MS show the strongest associations.

The regression coefficients dry strength (D) and sensitivity to water content (W) were derived from linear regression of VWC % against AF (Figure 3) for the normal and ln transformed data. The relationship between AF and VWC % for Constructed Subsoil 1b (Figure 3) is summarised by the equation y = 0.79x + 5.01 where the intercept (5.01) is ln D and the slope (-0.79) is W. The strength of the mine soil material increases as water content decreases and the functional form is best described by the ln/ln relationship. A summary of the regression coefficients for the ln/ln relationship indicates that a systematic relationship between ln D and W exists for the mine soil materials (Figure 4).

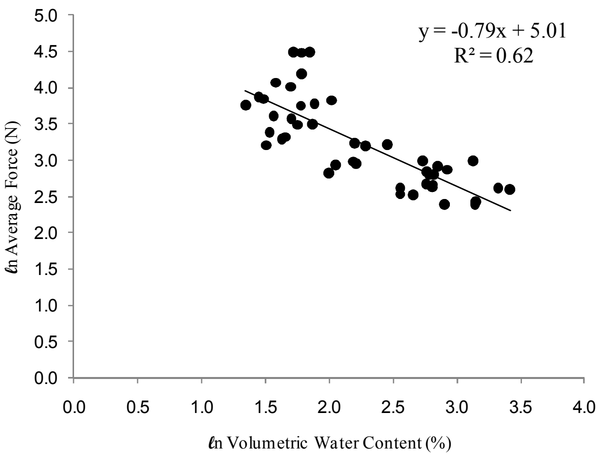

Figure 3. Relationship between ln AF (N) vs. ln VWC % for Constructed Subsoil 1b.

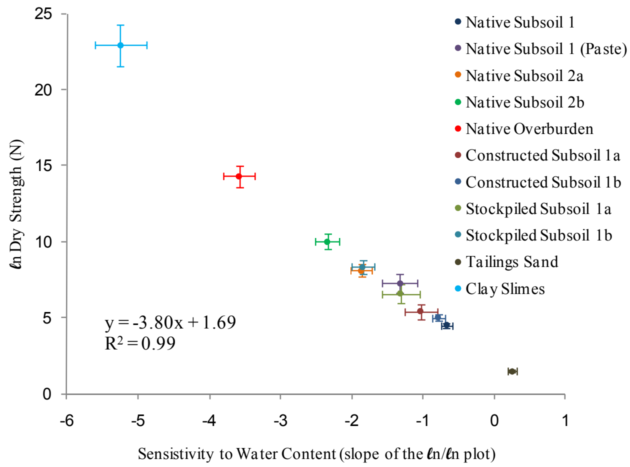

Figure 4. Relationship between ln D vs. W (slope of the ln/ ln **plot) with SE bars for the mine soil materials.**

Principal component analysis (PCA)

PCA identified clusters of closely correlated variables for the quartz, clay and voids fabric components of the mine soil materials. Five distinct groups of variables occurred for the quartz and voids components and four for the clay matrix. The grouping of variables was consistent across the fabric components and several of these properties are strongly positively correlated. On this basis, a subset of ImageJ parameters was selected to simplify the subsequent analysis of these data. These parameters are particle, aggregate and void size (Ad), length (Jd), roundness (Cm), sorting (Js) and size distribution (Fw). The ImageJ estimates of quartz (%Q), clay matrix (%M), void (%V), organic material (%O) and heavy mineral (%H), and the variables dry strength (D), sensitivity of strength to water content (W), and laboratory measured percent clay (C) were incorporated into the statistical analysis (Figure 5).

Eigenvalues determine the number of factors required to adequately classify the materials. In this instance, a four component model is sufficient to explain 83% of the variation in ImageJ parameters and the soil property variables. The strongest positive correlation is between D and %M (r = 0.90). This, together with the strong, positive correlation between D and C (r = 0.78) and a strong, negative relationship between D and %Q (r = -0.83), show that the strength of the mine soil materials is strongly dependent upon clay content. Sensitivity of strength to water content (W) is negatively correlated with M (r = -0.67) indicating that the strength of clay rich materials is most sensitive to water content (Figure 6).

D	**Dry Strength (N)**
W	**Sensitivity to Water Content**
C	**Clay (%)**
%Q	**Quartz (% of the image)**
%M	**Clay Matrix (% of the image)**
%V	**Voids (% of the image)**
%O	**Organic Material (% of the image)**
%H	**Heavy Mineral (% of the image)**
VAd	**Voids Area (mm^2) median**
VFw	**Voids Feret's Diameter skewness**
QJd	**Quartz EllipseMaJormedian**
QCm	**QuartzCircularitymean**
MAd	**Clay Matrix Area (mm^2) median**
MCm	**Clay Matrix Circularitymean**
MFw	**Clay Matrix Feret's Diameter skewness**

Figure 5. The reduced dataset consisting of the mine soil property variables and the ImageJ parameters.

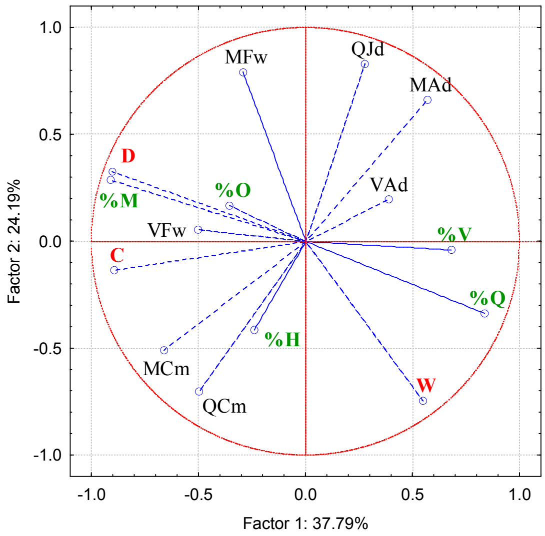

Figure 6. Relationships between the mine soil property variables and ImageJ parameters derived by PCA.

Conclusions

The parameters that best describe variations in soil fabric were established from PCA of the measured soil properties and the ImageJ parameters. The mine soil materials that are high in clay are stronger and strength is more sensitive to water content. The strong, positive relationship between laboratory measured clay content (C) and the ImageJ estimate of percent clay (M) indicates that the ImageJ analysis of thin section micrographs is a suitable tool for estimating the clay content of the mine soil materials. These results have implications for the management of mine soil materials during mining operations. The bulk-handling of mine soil materials may be necessary due to the large scale of mining operations, however these data indicate that their separate handling based on clay content may reduce the occurrence of hardsetting.

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Comparing the sensitivity of physical, chemical and biological properties to a gradient of induced soil degradation

Guilherme Montandon Chaer[A] and Marcelo Ferreira Fernandes[B]

[A]Embrapa Agrobiologia, Seropédica, RJ, Brazil, Email gchaer@cnpab.embrapa.br
[B]Embrapa Tabuleiros Costeiros, Aracaju, SE, Brazil, Email marcelo@cpatc.embrapa.br

Abstract
Soil biological and biochemical properties have been proposed as sensitive indicators of soil degradation. Nevertheless, their potential to predict the deterioration of major soil functions related to physical stability, and water and nutrient storage and fluxes has not been validated under experimental conditions. The sensitivity of 16 biological and biochemical variables was contrasted with other eight of chemical or physical nature in a gradient of soil degradation induced by cycles of one, two, three, or four tillage events, plus a no-till control. Twenty-four variables were analysed in soil samples (0-20 cm) collected 60 d after the last cycle. Out of these, 22 were significantly affected by soil disturbance. Six biological (microbial biomass-C, -N, and -C to N ratio; qMic; FDA and urease), two physical (water stable aggregates and aggregate mean diameter) and one chemical variable (org-P) were highly sensitive to soil disturbance. Soil bulk density, invertase activity, organic C and CEC were only slightly sensitive to tillage, whereas qCO_2 and xylanase were not significantly affected by tillage frequency. Although some biological and biochemical properties were highly responsive to soil degradation, there was no general trend of superiority of these variables over those of chemical and physical natures regarding the sensitivity to soil degradation.

Key Words
Soil quality; microbiological indicators; soil enzymes.

Introduction
The search for indicators that may anticipate soil degradation by unsuitable management practices has been one of the main soil scientists' challenges over the past 20 years. Because of the readiness of response of microorganisms to changes in soil environment, soil biological and biochemical properties have been widely proposed as sensitive indicators of soil degradation. Nevertheless, their predictive potential to indicate degradation of major soil functions related to physical structure stability and water and nutrient storage and fluxes has not been validated under experimentally controlled conditions. Here we compared in a tropical kaolinitic soil the sensitivity of a suite of fundamental physical and chemical soil quality indicators with several biological and biochemical variables across an induced gradient of soil degradation.

Methods
Experimental setting
This work was carried out in the Umbauba Experimental Station (Embrapa Coastal Tablelands, Umbauba, Sergipe State, Brazil) in a Typic Fragiudult. This area had been under fallow for 12 years before the beginning of the experiment. Experimental plots (36 x 12 m) were laid out in a Latin Square design with five treatments defined by the application of zero, two, four, six, or eight tillage events (TE). Each event was composed by two disk plowing alternated with two harrowing operations. Treatments were imposed in two cycles between July and September 2006, and November 2006 and March 2007. Within each cycle, events were applied every 15 to 30 days. Between September 2006 and November 2007, vegetation in the plots was controlled by monthly mowing.

Soil sampling and analyses
Sixty days after the last tillage event, soil samples were collected (0-20 cm depth) and analyzed for the following physical and chemical variables: CEC at pH 7.0 (Embrapa 1997); soil organic matter (ignition method); organic P (Anderson and Ingram 1996); available water between -10 e -1500 kPa (pressure plate; Dane and Hopmans 2002); soil bulk density (7,5 to 12,5 cm depth); saturated hydraulic conductivity (double concentric ring method; Reynolds *et al*. 2002); wet aggregate stability and aggregate mean weight diameter (Nimmo and Perkins 2002). Parallel analyses were performed for the following biological and biochemical properties: activity of soil enzymes associated with the cycles of carbon (β-glicosidase (Eivazi and Tabatabai 1988), cellulase, xylanase and invertase (Schinner and Von Mersi 1990), phenol oxidase (Sinsabaugh *et al*.

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1999)), nitrogen (urease; Kandeler and Gerber 1988), phosphorus (acid phosphatase; Tabatabai 1994) and sulfur (arylsulfatase; Tabatabai 1994); fluorescein diacetate hydrolysis (Schnürer and Rosswall 1982); basal soil respiration (Isermeyer 1995); microbial biomass -C and -N (Vance *et al*. 1987; Joergensen and Brookes 1990); and glomalin content (Wright and Upadhyaya 1998). The variables metabolic quotient (qCO_2), microbial quotient (qMIC) and microbial biomass C to N ratio were calculated from the analytical data.

Data analysis

The sensitivity of the indicators to the induced gradient of soil degradation was accessed by the linear regression of the data for each variable as a function of the number of TE, and by the use of contrasts (t-test) between each TE level and the non-till control. The indicators were ranked in the following classes according to their sensitivity to soil disturbance: “very high”, “high”, “medium”, “low”, “very low” and “non-sensitive”. The class “very high” was assigned to variables that had both a significant slope coefficient ($p<0.05$) in the linear regression and whose values at ≥ 2 TE differed significantly ($P<0.01$) from the non-till control. The criteria for the assignment of a variable to the class “high” were the same as for the class “very high”, except that differences between ≥ 2 TE plots and the non-till control were between 1 and 5% of significance ($0.01 < p < 0.05$). The classes “medium” and “low” were assigned to variables with a significant slope coefficient in the regression analysis and whose values differed from the non-till control at ≥ 4 TE and ≥ 6 TE, respectively. Variables that showed no significant differences between TE plots and the no-till control, but had a significant slope coefficient, were classified as of “very low” sensitivity, whereas those that did not show significant differences regarding any of the two statistical criteria were considered as “non-sensitive”.

Results

Mechanical disturbance applied to the soil in two cycles of plowing and disking operations led to significant changes in 22 out of 24 variables tested as soil quality indicators (Table 1). The only two variables that showed no response to mechanical disturbance were qCO_2 and xylanase activity. According to the criteria of sensitivity to soil mechanical degradation, physical, chemical and biological variables were ascribed to six different classes (Table 1). Seven variables, including four biological (microbial biomass-C and -N, qMIC and microbial biomass C to N ratio), two physical (wet aggregate stability and aggregate mean weight diameter) and one chemical (organic P) were classified as of “high sensitivity” to the induced disturbances. Two biological variables (fluorescein diacetate hydrolysis and urease activity) presented “high” sensitivity, whereas seven other variables of the same nature (β-glucosidase, acid phosphatase, arylsulfatase, basal respiration, phenol oxidase, glomalin content and cellulose activity) and two physical variables (saturated hydraulic conductivity and available water) were classified as of “medium” sensitivity. Three variables, soil bulk density, invertase activity, and organic C, were placed in the “low sensitivity” class, and one, CEC at pH 7.0, in the “very low” class. The great majority of the variables affected by mechanical disturbances presented a significant linear decrease in response to the soil degradation gradient (Table 1). However, increasing values along this gradient were observed for microbial biomass C to N ratio, phenol oxidase activity, and soil bulk density.

Conclusion

This is the first study to contrast, in a gradient of induced soil degradation generated under experimental conditions, the sensitivity of a range of biological and biochemical variables and ones of physical and chemical nature of relevance to soil quality. The application of increasing levels of soil tillage events was an efficient method to generate, under experimental conditions, a gradient of soil degradation. This gradient allowed us to study the response and rank the sensitivity to soil degradation of several soil chemical and physical properties in contrast to others of a biological nature. Our results showed that changes in most biological properties coincided with negative changes in soil chemical and physical properties. Although many biological and biochemical properties were highly sensitive indicators of soil degradation, there was no dominance of these properties over chemical and physical ones.

Table 1. Response and sensitivity class of soil physical (P), chemical (C) and biological (B) properties† to the tillage-induced soil degradation. Soil variables were ranked in descending order of sensitivity.

Class of sensitivity	Type of variable	Soil variable	Number of tillage events (TE)					Linear regression model	R^2
			0	2	4	6	8		
Very high	B	MBC (µg C/g)	227.4	183.4***	152.8***	132.2***	134.9***	Y = -23.6*** TE + 213.4	0.86
Very high	B	MBN (µg N/g)	50.8	34.9***	27.3***	24.1***	23.1***	Y = -6.6*** TE + 45.3	0.81
Very high	B	*q*MIC (%)	0.936	0.788***	0.673***	0.604***	0.611***	Y = -0.080*** TE + 0.88	0.83
Very high	B	MB C:N ratio	4.63	5.35**	5.71***	5.68***	5.99***	Y = -0.30*** TE + 4.86	0.82
Very high	F	Water stable aggregate (%)	67.1	54.4**	48.3***	40.7***	45.0***	Y = -5.78*** TE + 62.7	0.71
Very high	F	Aggregate mean diameter (mm)	1.28	0.93**	0.70***	0.62***	0.63***	Y = -0.16*** TE + 1.15	0.75
Very high	Q	Organic P (µg/g)	95.8	70.7**	68.7**	60.7***	67.3**	Y = -6.7*** TE + 86.0	0.68
High	B	FDA hydrolysis (µg fluorescein/g/h)	98.9	80.7*	70.4***	60.7***	62.4***	Y = -9.30*** TE + 93.2	0.71
High	B	Urease (µg N-NH_4^+ /g/h)	5.99	4.77*	4.45**	4.13***	3.50***	Y = -0.56*** TE + 5.69	0.75
Medium	B	β-Glucosidase (µmol PNP/g^{-}/h)	0.74	0.70	0.52***	0.43***	0.39***	Y = -0.10*** TE + 0.75	0.89
Medium	B	Acid phosphatase (µmol PNP / g/h)	7.05	7.07	5.96**	5.47***	5.41***	Y = -0.49*** TE + 7.17	0.86
Medium	B	Arylsulfatase (µmol PNP / g/h)	1.53	1.23	1.01**	0.69***	0.60***	Y = -0.24*** TE + 1.49	0.84
Medium	F	Hydraulic conductivity (cm /h)	19.04	14.17	4.67**	4.47**	4.05**	Y = -3.97*** TE + 17.2	0.67
Medium	B	Respiration (mg C-CO_2 /kg/d)	8.31	7.90	6.50*	5.60***	4.90***	Y = -1.24*** TE + 11.58	0.79
Medium	B	Laccase (nmol DIC /g^{-}/h)	4.82	4.88	6.29*	6.70**	8.07***	Y = 0.83*** TE + 4.50	0.80
Medium	B	Glomalin (µg eq. BSA/g)	2455	2290	2212*	2070**	1875***	Y = -138*** TE + 2456	0.78
Medium	F	Available water (m^3/m^3)	0.262	0.258	0.228*	0.213**	0.208**	Y = -0.015*** TE + 0.26	0.80
Medium	B	Cellulase (µg glucose /g^{-}/h)	64.9	60.0	56.4*	54.8*	53.3**	Y = -2.85*** TE + 63.6	0.77
Low	F	Bulk density (m m^{-3})	1.67	1.63	1.72	1.79***	1.83***	Y = 0.047*** TE + 1.63	0.74
Low	B	Invertase (µg glucose /g^{-}/h)	45.4	42.3	41.4	35.2**	26.8***	Y = -4.43*** TE + 47.1	0.81
Low	Q	Organic C (mg/g)	25.2	25.4	23.5	22.7*	21.2**	Y = -1.13*** TE + 25.0	0.73
Very low	Q	CEC ($cmol_c/dm^3$)	5.31	5.29	5.15	5.05	4.98	Y = -0.090* TE + 5.33	0.72
Non-sensitive	B	qCO_2 (mg C-CO_2 /mg MBC/d)	0.038	0.044	0.044	0.042	0.037	-	-
Non-sensitive	B	Xylanase (µg glucose/g/h)	35.1	26.6	63.8	53.5	41.3	-	-

***P<0.001; **P<0.01; *P<0.05.

† Values of soil properties were adjusted to account for row and column effects associated with the Latin Square design.

MBC, microbial biomass carbon; MBN, microbial biomass nitrogen; *q*MIC, (MBC*1000/ organic C)*100; FDA, fluorescein diacetate; PNP, *p*-nitrophenol; DIC, dihydroindole–quinone–carboxylate; BSA, bovine serum albumin; qCO_2, respiration/MBC.

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Comparison of methods for soil acidity measurement in Nyírlugos (Hungary) long-term field expriment

Imre Vágó[A], László Tolner[B], Imre Czinkota[B], Márk Rékási[C] and Imre Kádár[C]

[A]Faculty of Agricultural Science, University of Debrecen, Böszörményi Street 138, H-4032, Hungary, Email: vago@agr.unideb.hu
[B]Faculty of Agriculture and Environmental Sciences, Szent István University, Gödöllő, Páter K. Street 1, Hungary, E-mail: Tolner.Laszlo@gmail.com, Imre.Czinkota@gmail.com
[C]Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, Herman Ottó Street 15. E-mail: Rekasi@rissac.hu, kadar@rissac.hu

Abstract
Soil acidification and the amelioration of acidic soils is a world wide problem. Acid soils occupy approximately 30% of the world's ice free land area. The knowledge of the exact value of soil acidity is important because of lime requirement estimation, thus the amelioration and protection of soils. In Hungary and in some other countries the $CaCO_3$ amount needed to ameliorate acid soils is calculated by considering their hydrolytic acidity (y1). In the measurement suggested by Kappen (1929) the acidity of the equilibrium solution of the soil's Ca-acetate extract is quantified. The amount of acidity titrated in the equilibrium solution depends on the acidity of the soil and on the suspension pH. To determine the total releasable surface acidity the soil must be continuously percolated or the soil/extractant ratio must be changed. For the elimination of this principle error of Kappen's method the soil acidity can be determined by the pH-stat titration of the soil suspension. Our results show that the new method can characterise quantitatively soil acidity thus it can give the basis for the lime requirement calculation.

Key Words
Soil acidity, slow titration, brown forest soil, long-term field experiment

Introduction
The soil's basic functions may suffer a loss by natural or anthropogenic acidification. Soil acidification and the amelioration of acidic soils is a world wide problem. Acid soils occupy approximately 30% of the world's ice free land area. In Hungary this problem has a great importance because the area susceptible for acidification covers more than the half of the country's land. The knowledge of the exact value of soil acidity is important because of lime requirement estimation, thus their amelioration and protection of soils (Uexküll - Mutert 1995; Várallyay *et al.* 1980).
For the investigation of mineral fertilization and liming a field experiment was set up in Nyírlugos on acidic sandy brown forest soil with alternating thin layers of clay substance „kovárvány" by Láng István (1973). By now this experiment is one of the oldest in Hungary. The treatments of the experiment can be seen in Table 1.

Table 1. Fertilization and liming treatments in the experiment, kg/ha/yr (Brown forest soil, acid sand, Nyírlugos, Nyírség region, Hungary) (Kádár 2007)

Nutrient levels	Applied nutrients				
	N	P_2O_5	K_2O	$CaCO_3$	$MgCO_3$
0	0	0	0	0	0
1	50	60	60	250	140
2	100	120	120	500	280
3	150	180	180	1000	-

As a result of the treatments the soil properties (CEC, pH, hydrolytic acidity) has changed (Kádár 2007). Thus the soils of different treatments can serve as a basis of the comparison of different acidity measurement methods.

In Hungary and in some other countries the $CaCO_3$ amount needed to ameliorate acid soils is calculated by considering their hydrolytic acidity (y1). In the measurement suggested by Kappen (1929) the acidity of the equilibrium solution of the soil's Ca-acetate extract is quantified. The amount of acidity titrated in the equilibrium solution depends on the acidity of the soil and on the suspension pH. But this acidity value does not equal to the total amount of releasable H^+. It shows only the equilibrium value corresponding to the given

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soil/extractant ratio. To determine the total releasable surface acidity the soil must be continuously percolated or the soil/extractant ratio must be changed (Filep 1999). For the elimination of this principle error of Kappen's method the soil acidity can be determined by the pH-stat titration of the soil suspension (Czinkota *et al.* 2000).

Methods

For the experiment 6 treatments of the field experiments soil was investigated: control, N_1, N_2, N_3, $N_2P_2K_2Ca_3$, $N_2P_2K_2Mg_2$. The properties of samples are shown in Table 2.

Table 2. Properties of the investigated soils (Kádár 2007)

Treatment code	pH (H_2O)	pH (KCl)	Hydrolytic acidity, y_1	CEC	Sum of bases
				meq/100g	
Control	5.4	4.3	7.6	3.4	1.2
N_1	5.0	4.2	9.6	3.4	0.7
N_2	4.7	3.6	12.6	3.4	0.5
N_3	4.6	3.5	13.6	3.3	0.4
$N_2P_2K_2Ca_3$	6.8	6.4	3.6	3.6	2.5
$N_2P_2K_2Mg_2$	6.3	6.0	4.8	3.8	2.2

The hydrolytic acidity values were determined according to Kappen (1929). The samples were treated with 0.5 M/dm^3 Ca-acetate solution adjusted to pH 8.2 in the ratio of 1:2.5). The suspensions were shaken at room temperature for one hour then filtrated. The filtrates were titrated with 0.1 M/dm^3 NaOH solution in presence of phenolphthalein indicator and the hydrolytic acidity values were calculated from the amount of alkali consumed (0.1 M/dm^3 NaOH cm^3 for 50 g soil). The pH-stat titrations were carried out in 0.01 M/dm^3 $CaCl_2$ solution with the titration equipment designed for this purpose (Czinkota *et al*. 2002). The titrations themselves were performed in a 1:25 ratio 0.01 M/dm^3 $CaCl_2$ solution suspensions. The fixed limit value of the titration was pH = 6.5.

Results

The titration curves of the soils of different treatments are shown in the Figure 1. The endpoint of the titration could be determined by extrapolation.

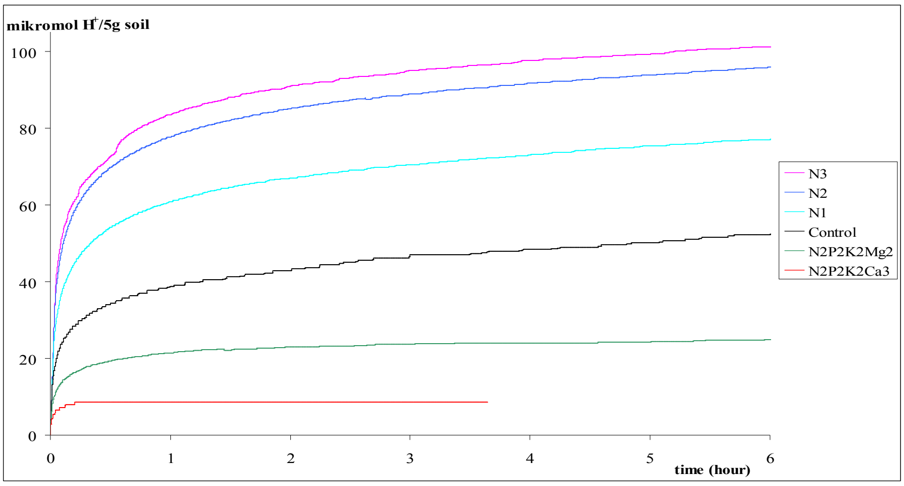

Figure 1. Titration curves of the soils of different treatments in the average of 4 replications.

The reliability of the extrapolated values is based on applied mathematical model. In our previous research works the proton exchange reactions were described as the sum of two first order kinetic equations (Filep and Csubák 1997):

$$\mathbf{y = A_0 + A_1*(1-e^{-k1t}) + A_2*(1-e^{-k2t})} \quad (1)$$

where:

C amount of base or acid to reach the given pH, meq/100g

y amount of fed base or acid, meq/100g

t	time, sec
a_1	base or acid consumption of faster process, meq/100g
a_2	base or acid consumption of slower process, meq/100g
k_1	rate constant of faster process, s^{-1}
k_2	rate constant of slower process, s^{-1}

The 5 parameters of the model (A_0, A_1, A_2, k_1, k_2) were calculated by non-linear regression. The estimations of the parameter values are not independent from each other. Especially the different combinations of A_1 - k_1 and A_2 - k_2 parameter pairs may give models that describe the measured values with the same reliability. This phenomenon can cause problems if the task the comparison of different soil samples is. That is why the model should be modified: the parameters must be independent, the number of parameters should be as small as possible and the complete exponential model must be transformed into a linear model (Tolner, L. and Füleky, Gy. 1995).

To solve these problems the following function were used:

$$\mathbf{y = A_0 + A_1*(1-e^{-k1t}) + A_2*(1-e^{-k2t}) + A_3*(1-e^{-k3t}) + A_4*(1-e^{-k4t})} \qquad (2)$$

For the model fitting the k parameters were constant (k_1=12,0; k_2=3,0; k_3=1.0; k_4=0,08) so as the A – k pairs with the same index were independent. The model with these parameters reach the 99% of alkali consumption as presented in Table 3.

Table 3. The time required to reach the 99% of base consumption of the reactions with different rate values (k)

k	12.0	3.0	1.0	0.08
Required time (hours)	**0.38**	**1.53**	**4.60**	**57.56**

With the combination of reactions with different rate constant gave a well fitted model (Table 4).

Table 4. Parameter values of the titration N_3 treatment soil (I - IV replications)

Parameters / replications	I.	II.	III.	IV
$\mathbf{A_0}$	208.2	199.8	205.6	131.8
$\mathbf{A_1}$	199.5	235.7	199.9	330.1
$\mathbf{A_2}$	90.2	121.4	111.4	0.0
$\mathbf{A_3}$	155.7	165.7	113.4	388.1
$\mathbf{A_4}$	247.6	337.6	295.8	166.7
$\mathbf{A_0 + A_1 + A_2 + A_3 + A_4}$	**901.2**	**1060.2**	**926.1**	**1016.7**
g soil	4.8556	4.9322	5.0264	5.0155
In the measure of y_1*	**11.79**	**13.66**	**11.71**	**12.88**

* consumed cm^3 of 0.1 M/dm^3 NaOH to titrate back 50 g soil after 1 hour shaking with 0.5 M/dm^3 Ca-acetate solution (pH 8.2)

In the column of replication IV (Table 4) can be seen that not all titrations can divide into 4 different rated reactions. In this case the A_2 value of the reaction with k_2=3.0 was 0.0.
The calculation was carried ot with a 4 parameter linear regression according to the following model:

$$\mathbf{y = A_0 + A_1*z_1 + A_2*z_2 + A_3*z_3 + A_4*z_4} \qquad (3)$$

where: $\mathbf{z_1 = 1-e^{-k1t}}$ $\mathbf{z_2 = 1-e^{-k2t}}$ $\mathbf{z_3 = 1-e^{-k3t}}$ $\mathbf{z_4 = 1-e^{-k4t}}$
The sum of base consumption ($A_0 + A_1 + A_2 + A_3 + A_4$) was calculated in case of each replications from the A values resulted from the regression. These values represent the alkali consumption extrapolated for infinite time. These values are determined by the acidity releasable from the surfaces of soil colloids. The titrated acidity values were given in the measure of y_1. The averages of different treatments can be seen in Table 5.

Table 5. The titrated acidity values in case of different treatment soils

Measured and calculated characteristics	Treatments code						LSD$_{5\%}$
	N$_3$	N$_2$	N$_1$	Control	NPKMg	NPKCa	
titration μmol/5g soil	125.1	116.1	93.8	70.8	30.9	8.6	
In the measure of y_1^*	12.51	11.61	9.38	7.08	3.09	0.86	2.00

* consumed cm^3 of 0.1 M/dm^3 NaOH to titrate back 50 g soil after 1 hour shaking with 0.5 M/dm^3 Ca-acetate solution (pH 8.2)

For the validation of titrated acidity values the results were correlated with the difference between CEC and sum of exchangeable basic cations (CEC-BC). The CEC-BC values can conclude to the amount of ions causing acidity (Al^{3+} + H^+) (Table 6).

Table 6. Acidity of the investigated soil samples detemined with different methods: according to Kappen (1929) – y1 and the the difference between CEC and sum of exchangeable basic cations (CEC-BC)

Measured and calculated characteristics	Treatments code						LSD$_{5\%}$
	N$_3$	N$_2$	N$_1$	Control	NPKMg	NPKCa	
CEC-BC (meq/100 g)	2,9	2,9	2,7	2,2	1,6	1,1	0,4
Hidrolytic acidity (y1)	13,6	12,6	9,6	7,6	4,8	3,6	2,1

Both of the acidity values measured by traditional (Kappen, 1929) and new titration method resulted the same LSD$_{5\%}$ values (Table 5 and 6).

Conclusion

It can conclude from the above that the new method can characterise quantitatively soil acidity thus it can give the basis for the lime requirement calculation.

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Deviation in soil colour determination based upon students visual perception

Csaba Centeri[A], Márton Vona[B] and Zsolt Bíró[C]

[A]Department of Nature Conservation and Landscape Ecology, Institute of Environmental and Landscape Management, Faculty of Agricultural and Environmental Sciences, Szent István University, 2103-Gödöllő, Páter K. u. 1., Hungary, Email Centeri.Csaba@kti.szie.hu
[B]Central Directorate for Water and Environment, H-1012, Budapest, Márvány u. 1/D., Hungary, Email: Vona.Marton@vkki.hu
[C]Institute for Wildlife Conservation, Faculty of Agricultural and Environmental Sciences, Szent István University, 2103-Gödöllő, Páter K. u. 1., Hungary, Email bzsolt@ns.vvt.gau.hu

Abstract
The determination of soil colours is essential not only in soil science research but on other areas (e.g. forestry), too. Twenty samples were collected from various parts of Hungary and air dried. 110 bachelor students were chosen to identify the soil colours. They used the Munsell Soil Colour Charts. The twenty samples were identified in dry and in wet conditions. Statistical analyses were done by the SPSS program. Groups were made of the basic data to compare the recognition of colours. X^2 probe was used to tell if there were any differences between the males and females, and Kruskal-Wallis test with Dunn's post hoc test to tell the difference between dry and wet soils' value and chroma values. Males and females recognized the wet and dry values of the examined soils approximately at or around the same spots, however the differences grew during the recognition of wet values, but it was not significant. The Kruskal-Wallis test with Dunn's post hoc test showed that in most of the cases there were 5 or 7 similar groups of soil colours in the 20 examined samples. It is visible that soils No. 4, 10, 14 and 17 have different colours. It was proven by the analyses, too. We can state that the difference of lighter colours from darker colours can be proven with analysing the Dry Value. Soil No. 16 had the most (9) similar pairs during the analyses of the Dry Values. The analyses of the Dry Chroma and the Wet Value of the samples proved soils No. 10, No. 14 and No. 17 to have the lowest number (3-4) of similar pairs, so they are proved to be different from other samples.

Key Words
No more than six key word items in order of decreasing relevance.

Introduction
The determination of soil colours is essential not only in soil science researches but on other areas (e.g. forestry), too. Wills *et al.* (2007) evaluated soil colour measurements to predict soil organic carbon (SOC) for agriculture and prairie land uses. In soil science one of the most widely used methods to classify soil colours is using the Munsell® Soil Colour Chart.

A cross-plot of Munsell values and their SOC concentrations revealed characteristic, non-overlapping areas for each particle-size class and the bulk soils. Clay-size separates and bulk soils were almost identical in Munsell values, although for clay-size separates SOC concentrations were much larger than for bulk soils (Wiesenberg *et al.* 2006).

The type of colour model to use will depend on the purpose. If soil colour is being used for merely descriptive purposes, then the Munsell HVC system will remain appropriate. If it is being used for numerical statistical or predictive analysis, then colour models that use Cartesian-type coordinate systems will be more useful (Rossel *et al.* 2006).

Munsell colour identification system was used for various other purposes, not only for soil colour classification. Pross *et al.* (2007) determined the colours of six sporomorph groups from geological drillings using Munsell colour standards under reproducible optical conditions. Hytonen and Wall (2006) used colours to find the correlations between colour attributes and foliar nutrient. Concentrations were at their highest when colour was measured from the tips of fresh needles. Singh *et al.* (2006) used remotely sensed data to determine soil degradation processes by soil colours, using the Munsell Colour System.

There were numerous attempts to make soil colour recognition more proper. Benavente *et al.* (2006) used a data set of 387 colour reflectance for scoring method to collect a set of judgments adequate for the fuzzy modelling of a colour-naming task. Laamanen *et al.* (2006) presented a novel general transformation between reflectance spectra and the corresponding coordinates of the Munsell Colour System. Romney and Fulton (2006) present a method for transforming reflectance spectra into Munsell colour space by using hypothetical absorbance curves based on Gaussian approximations of the prime colours and a simplified version of opponent process theory.

Several authors investigated some special parts of the Munsell Soil Colour Chart, e.g. Pridmore (2007) had experiments with effects of purity on hue in various conditions; Thulasidas *et al.* (2006) had experiments with hue and chroma.

Cheung and Westland (2006) described methods to select optimum colour samples from a set of 1269 Munsell surface colours. The work proves that it is possible to select 24 samples from the Munsell set that outperform the GretagMacbeth ColourChecker and that this selection can be efficiently derived using an algorithm called MAXMINC.

Lehtonen *et al.* (2006) explain a method for calculating the optimal sampling interval of colour spectra (1269 samples were used). It is shown that a 20 nm interval is enough for the smooth Munsell set alone, but 10 nm is not enough for the same set matched with a fluorescent light source. 5 nm was enough in most situations. Matz and Figuero (2006) introduced a nonlinear local contrast enhancement method. This method utilizes the Munsell value scale which is based upon human visual perception. Use of the Munsell value scale allows for the partitioning of the grey scale into ten discrete subintervals.

Our aim was to find out if there were any identifiable group of soils statistically and if there were any difference between the recognition of hue, chroma and value of the 20 examined soils with the 110 students.

Methods

Twenty samples (from topsoil, B horizon and parent material) were collected and air dried from various part of Hungary to give a good range of the Hungarian soils. 110 bachelor students (age 18-20) were chosen to identify the soil colours. They used the Munsell Soil Colour Charts under the same lighting conditions. The twenty samples were identified in dry and wet conditions, too. Statistical analyses were done by the SPSS program. Groups were made of the basic data to compare the recognition of colours by males and females. X^2 probe was used to tell if there were any differences between the males and females, and Kruskal-Wallis test with Dunn's post hoc test to tell the difference between dry and wet soils' value and chroma values.

Results

Results with F probe

The first approximation of analysing the differences between the colours was the calculation of the standard deviation and the F probe. In case of Soil No. 1 the F probe of the values resulted <0.01, while the chromas resulted 0.9<, so the identification of the values and the chromas of this colour has to be investigated furthermore. It is the opposite with Soil No. 2, where both F probes of values and chromas resulted high F probe values (0.85<). There were extremities in case of the chroma of Soil No. 4 (7.67E-07) and No. 10 (8.26E-14); and No. 12 (2.17E-06). There were extreme differences between recognition of the following values and chromas: No. 1, No. 3, No. 4, No. 6, No. 7, No. 10, No. 13.

Results with X2 probe

Males and females recognized the wet and dry values of the examined soils approximately at or around the same chips; however the differences grew with finding the wet values (not significant). There are no differences between the recognition of dry and wet samples in case of females but there is in case of males. It is visible that the difference is caused by the recognition of the colours in the hues of 10YR and 2,5Y. The biggest difference was in case of 2,5Y. Male participants overuse 2,5Y during the recognition of dry samples and underused in case of the wet samples compared to the average of distribution of the samples.

Kruskal-Wallis test with Dunn's post hoc test

In most of the cases there were 5 or 7 similar soils in the 20 examined samples (Figure 1-4.). No. 4, 10, 14 and 17 are different from the other samples, No. 14 and No. 17 is reddish, No. 4. and No. 10 is whiter than the others. It is proven by the analyses, too.

Wet Chroma
The following examined soils belong to the same group (Figure 1a.):

- Wet Chroma Group 1: 1, 2, 7, 8, 9, 10, 11, 12 and 13;
- Wet Chroma Group 2: 5, 15, 16 and 20.

No. 14 is almost different from all the other soils. No. 17, 18 and 19 is a third group.

Wet Value
The following examined soils belong to the same group (Figure 1b.):

- Wet Value Group 1: 1, 7, 8, 9, 10, 11, 12, 13;
- Wet Value Group 2: 3, 4, 6, 16, 17, 18, 19, 20.

No. 10. and No. 14. have only 3 similar soils, No. 17. has only 4 similar soil in the dataset.

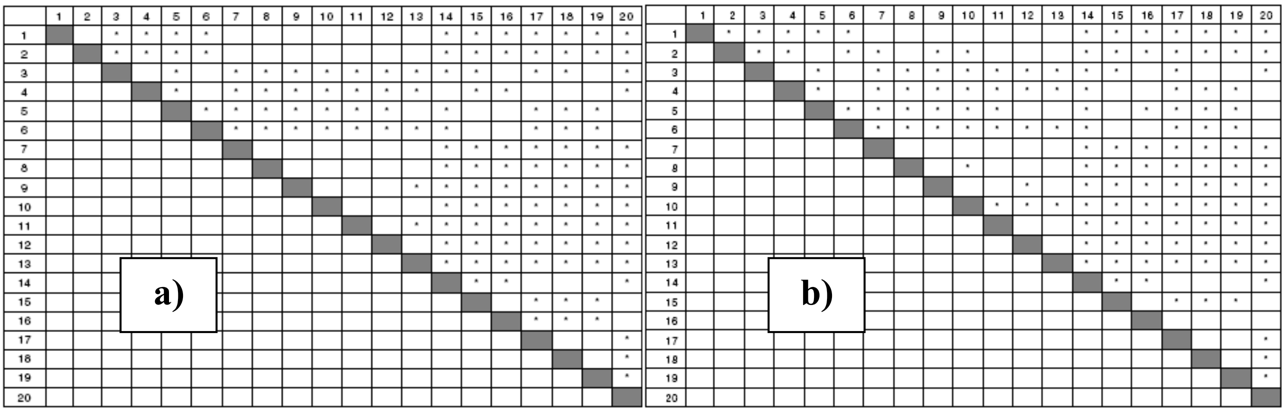

Figure 1a, b. Results of Kruskal-Wallis test with Dunn's post hoc test for a) Wet Chroma (*p<0,001, KW=1637, df=19) and b) Wet Value (*p<0,001, KW=1563, df=19)

Dry Chroma
The following examined soils belong to the same group (Figure 2a.):

- Dry Chroma Group 1: 1, 7, 8, 9, 10, 11, 12, 13;
- Dry Chroma Group 2: 4, 5, 6, 15, 16, 20.

In this case we find the same case with the lowest number of similar colours like in case of the Wet Value: "No. 10. and No. 14. have only 3 similar soils, No. 17. has only 4 similar soil in the dataset."

Dry Value
The following examined soils belong to the same group (Figure 2b.):

- Dry Value Group 1: 1, 2, 8, 9, 11, 12
- Dry Value Group 2: 3, 6, 7, 14, 15, 16, 17; and
- Dry Value Group 3: 13, 16, 18, 19, 21.

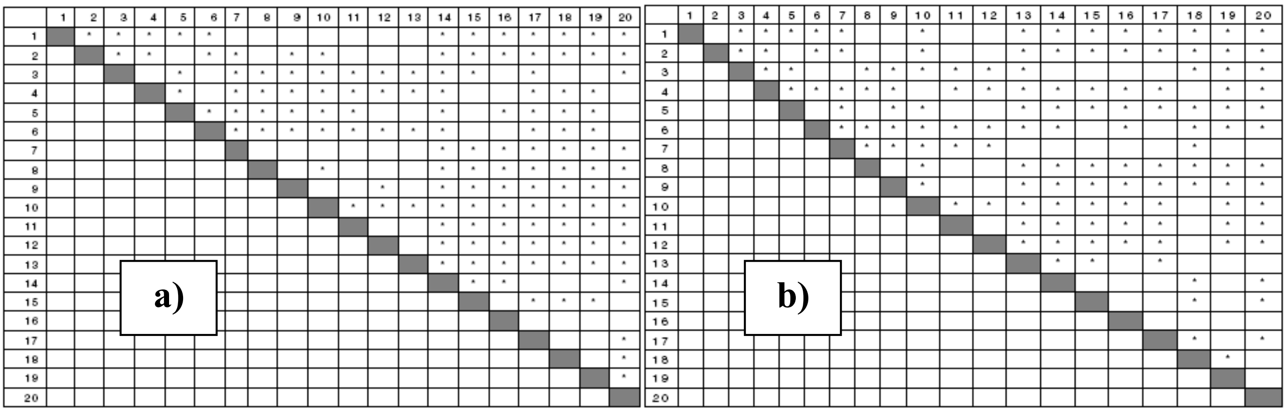

Figure 2a, b. Results of Kruskal-Wallis test with Dunn's post hoc test for a) for Dry Chroma (*p<0,001, KW=1711, df=19) and b) Dry Value (*p<0,001, KW=1736, df=19)

Dry values result the lowest number of pairs in the overall investigation. In this case soil No. 4. and No. 10. have only 2 similar soils.

Conclusion

We can state that the difference of lighter colours from darker colours can be proven with analysing the Dry Value. It is the same case with the highest similarity: soil No. 16. had the most, 9 similar pairs during the analyses of the Dry Values. The analyses of the Dry Chroma and the Wet Value of the samples proved soils No. 10, No. 14 and No. 17 to have the lowest number (3-4) of similar pairs, so they are proved to be different from other samples. Finally we can say that Wet Chroma did not prove the former statements about soils No. 4, No. 10, No. 14 and No. 17. Finally we can state that more experiments are needed in order to reach better results with soil colour identification since it is widely used in soil science as a limit of certain qualifiers in soil classification, and in other areas of everyday life, e.g. forestry, mining etc. More proper results can help to better understand soil degradation processes, to set limits of colour based separation of different diagnostic horizons in soil classification and to find the reason of coloration of the leaves in forestry.

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A soil invertebrate indicator for New Zealand pastoral soils

Nicole Schon[A], Maria Minor[B], Alec Mackay[C], Gregor Yeates[D] and Mike Hedley[E]

[A] Ecology Department, Massey University, Palmerston North, New Zealand, Email nicoleschon@gmail.com
[B] Ecology Department, Massey University, Palmerston North, New Zealand, Email m.a.minor@massey.ac.nz
[C] AgResearch, Palmerston North, New Zealand, Email alec.mackay@agresearch.co.nz
[D] P O Box 1758, Palmerston North, New Zealand, Email gregor.yeates@gmail.com
[E] Soil and Earth Science Department, Massey University, Palmerston North, New Zealand, Email m.hedley@massey.ac.nz

Abstract

Soil invertebrates play an important role in a wide range of soil processes. A soil invertebrate indicator for pastoral soils in New Zealand is being developed. The indicator aims to add to current understanding of the role soil biota play in the provision of soil services and to give land managers an insight of how their current system is affecting soil biology and the soil processes they contribute to.

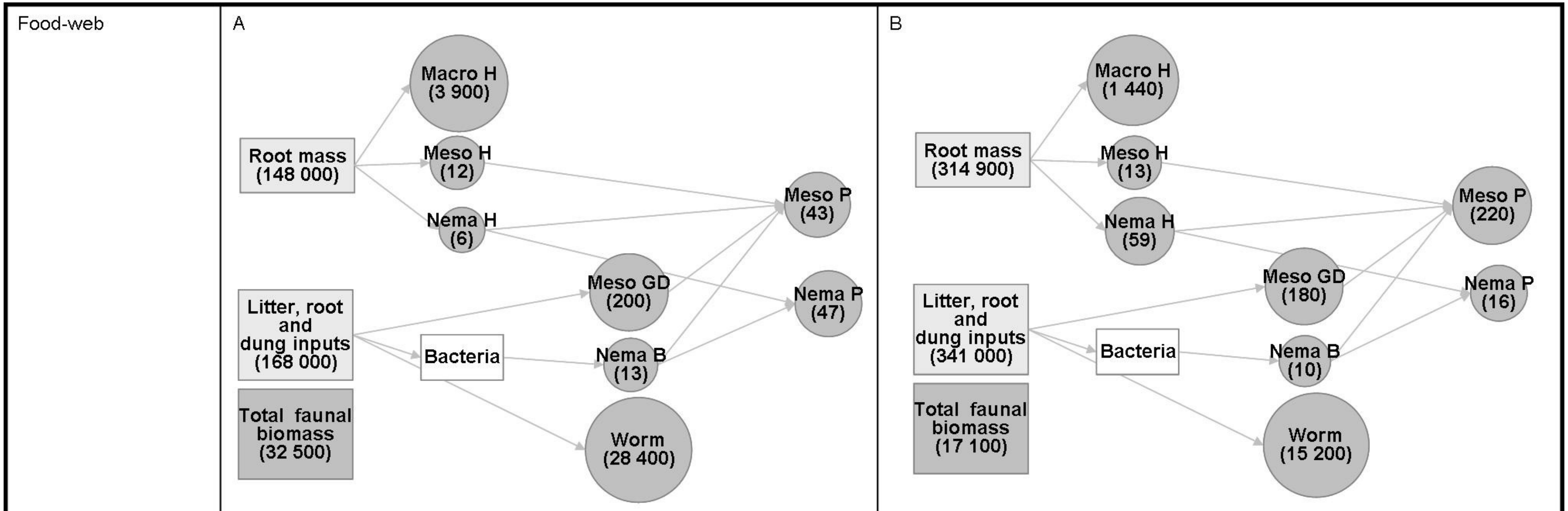
A large number of New Zealand sheep and dairy pastures across the major soil orders under different managements were sampled. The elements of the invertebrate indicator include the identification and quantification of selected soil invertebrates, as well as a measure of the food resources and habitable pore space available to the invertebrate community.

Key Words
Soil biological quality, soil functions, soil processes, soil invertebrates

Introduction
Soil invertebrate communities are important within the soil system and contribute to a wide variety of soil processes. While they operate at small scales they have large scale benefits for ecosystem services (Lavelle *et al.* 2006; Wall *et al.* 2004), some of which are seen in Visual Soil Assessment (Shepherd 2000). Highly modified pastoral systems, which are a feature of agriculture in New Zealand, affect the soil and its biology. Soils with diverse food webs may require fewer inputs to achieve higher productivity than those with food webs missing a vital component.

The aim of this study was to explore the relationships between pastoral management practices on a range of New Zealand soils and the diversity and quantity of soil invertebrates. The end goal was a soil invertebrate indicator related to observed differences in soil properties and processes. The indicator aims to add to the current measures of soil services (e.g. nutrient supply), and to give land managers greater knowledge of how their system is affecting soil biota and the processes they contribute to, including litter incorporation, nutrient cycling, soil aggregate building and soil pore construction. This may guide land managers to ensure their management practices sustain the required biological community.

Methods
In developing the soil invertebrate indicator a large number of pastures under a wide range of managements were sampled. These included a long-term comparison of conventional and organic sheep-grazed systems on a Brown soil (Ballantrae Research Station); four paired commercial organic and conventional farms on different soil types; a long-term sheep-grazed fertiliser trial with either 10 or 50 kg/ha of phosphorus applied as single superphosphate on an Allophanic soil (Whatawhata Research Station), and the influence of a combination of increasing dairy cow numbers, fertiliser application and feed supplements on an Allophanic and Gley soil in the Waikato (2.3, 3 and 3.8 cows/ha at Newstead) and on an Allophanic soil in Taranaki (3, 4 and 5 cows/ha at Whareroa). In addition, three fertiliser trials examining the interaction between phosphorus, nitrogen and irrigation on Allophanic, Brown and Pallic soils where grazing animals had been excluded were sampled.



	A	B
Stock type	Sheep	Dairy
Stocking rate (SU/ha)	14.5	25
Liveweight (kg/ha)	800	1 500
Soil type	Allophanic	Allophanic
P inputs (kg P/ha)	50	47
Pasture production (kg DM/ha)	12 300	14 000

Figure 1. Examples of soil food webs based on standing biomass of selected soil faunal groups and associated site properties for a A) sheep-grazed pasture and B) dairy-grazed pasture. Macrofauna (Macro), mesofauna (Meso) and nematode (Nema) herbivores (H) feed on plant material. Earthworms (Worm), mesofauna general detritivores (GD) and nematode bacterial-feeders (B) feed on detrital inputs and associated microflora. The macrofauna, mesofauna and nematodes are in turn consumed by predators (P). Circle sizes represent the logarithm of the faunal biomass, actual biomass (dry weight mg/m^2) given in parenthesis. Trophic groups, including fungal-feeders, with biomass <1.5 mg dry weight/m^2 were excluded.

At all sites soil invertebrates (macrofauna, mesofauna and nematodes) were identified and quantified along with information on soil chemical and physical properties. Other information collected included soil moisture, pasture production, fertiliser application, and stocking rate. The invertebrate data was used to produce a food web of standing invertebrate biomass under each soil and management (Figure 1). This was used in combination with estimated dry matter to the soil from grass, roots and dung; habitable pore space (measured using fluorescent resin and imaging software) and treading pressure, to better understand factors influencing the soil biological communities. This information forms the basis for the soil invertebrate indicator. High and low abundances of selected invertebrate groups were calculated as the upper and lower 10^{th} percentiles.

Results and discussion

Under pastoral management soil invertebrates are influenced by pasture production, which affects food availability; and by livestock type and density through physical disturbance and treading pressure, which act to compact the soil, decreasing habitable pore space. These two factors (food availability and habitable pore space) are moderated by other factors such as climate and soil type, both of which must be considered in quantifying the effects of pastoral agriculture on the density of the soil invertebrates across the diversity of soils found in New Zealand. The implications of having no, low and high abundances of selected important invertebrates for key soil processes are listed in Table 1.

A productive pasture is dependent on a supply of nutrients and water arriving at the root surface and the continuous exchange of carbon dioxide and oxygen to ensure optimum root function. The incorporation, mixing and decomposition of litter and assistance in maintaining pore function for rapid drainage after rainfall to ensure good aeration are also essential. Soil organisms which are conducive to these conditions need to be encouraged (van Eekeren *et al.* 2007).

Table 1. Draft soil invertebrate indicator and its parameters. Additional information might include soil type, stock type, stocking rate, fertiliser application rate, pasture growth, supplements fed to stock, and amount of dry matter to the soil. Invertebrates may be important for more than one soil service. If invertebrates are absent or low in abundance their populations need to be stimulated to improve the soil's performance*. Low and high abundances of invertebrates (ind./m^2) are given for average sheep and dairy grazed pastures.

Soil processes (contributing to a service/disservice)	Important invertebrates	Low	High	Sheep (Fig 1A)	Dairy (Fig 1B)
Water and air movement					
- creation of soil pores	Endogeic earthworm[1]	250	500	516	278
	Anecic earthworm[1]	0	150	0	18
- sensitive to treading pressures	Oribatid mite[1]	65	21 100	17 100	8 100
Nutrient cycling					
- litter incorporation	Anecic earthworm[1]	0	150	0	18
	Epigeic earthworm[1]	10	125	132	8
- nutrient rich faecal pellets	Oribatid mite[1]	65	21 100	17 100	8 100
- controlling other populations	Nematode[1]	550 000	1 180 000	881 200	985 300
- dominant food web pathway	Nematode Channel Ratio	0.72	0.93	0.94	0.87
- plant growth	Nematode Plant Parasite Indicator	0.60	1.55	0.88	1.44
	Herbivorous macrofauna[1]	5	325	106	71
Green house gas regulation					
- carbon storage	Anecic earthworm[1]	0	150	0	18
	Epigeic earthworm[1]	10	125	132	8
- nitrous oxide production	Endogeic earthworm[1]	250	500	516	278
	Anecic earthworm[1]	0	150	0	18

[1] abundances

* High value of the Plant Parasite Indicator may indicate suppressed net plant growth.

Interpretation of the condition of the soil invertebrate community utilises the information in Figure 1 and Table 1. The two examples illustrated in Figure 1 are located on the same soil order and have similar inputs of phosphorus fertiliser and litter to the soil, but differ markedly in stock type and associated live weight, as well as in the soil biological communities. In the sheep-grazed pasture the maintenance and creation of soil pores (particularly deep pores) is constrained by the absence of anecic earthworms. The high abundance of epigeic earthworms ensures good litter incorporation from the surface, but the absence of anecic earthworms may have implications for organic matter incorporation deeper into the soil. The food web is bacterial dominated, with the level of plant-feeding nematodes not likely to be suppressing plant growth. Of concern in the dairy cow grazed pasture, is the low abundance of endogeic earthworms for pore formation, and along with the low abundance of Oribatida suggests that the stock live weight loading is exerting significant pressure on soil structure in the root zone. In this example, the total live weight of dairy cows is more than twice that of sheep (Figure 1). The high Plant Parasite Indicator may also be of concern, but not the abundance of herbivorous macrofauna.

Conclusion

The soil invertebrate indicator has the potential to give land managers greater knowledge about the function of soil invertebrates in their soils. Land managers can add the invertebrate indicator to more visible measures of soil quality, and use it to optimise their practices. Pasture management that includes consideration of the invertebrate community has the potential maintain or promote soil structure and increase nutrient availability.

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Evaluation and importance of soil functions in cities considering infiltration and climatic regulation

Andreas Lehmann

Institute of Soil Science and Land Evaluation (310), University of Hohenheim, 70593 Stuttgart, Germany

Abstract
The functionality of natural extra-urban soils is now widely recognized in spatial planning after soil functions were introduced in the 1970s. However, the functionality of urban soils is often neglected in land-use planning despite the fact that biomass production, flood prevention, and ground water recharge are essential contributions of natural and anthropogenic urban soils for the livelihood of cities. Even less recognized but important are contributions of urban soils for sequestration of dust and carbon as well as their contribution to providing a comfortable urban climate by cooling and humidifying. Despite this, the significance of the functionality of soils during planning processes are often win-win situations for both, i.e. the quality of constructions and the quality of the urban environment. Furthermore, there is a significant potential to save money by considering the soil quality in planning and construction processes.

Key Words
Urban soils functions management evaluation climate

Introduction
Urban areas and the urban population grow rapidly since the 1930th. Globally, the proportion of people living in urban areas doubled since 1935, from approx. 25% to 50%. Thus, the functionality of soils in urban areas becomes more and more important for the quality of human life. Schematic soil evaluation systems have been mainly developed to assess a range of the functionality of natural soils. Relatively simple procedures have been developed to help in soil management. Otherwise, TUSEC (Technique for Soil Evaluation and Categorization for Natural and Anthropogenic Soils, Lehmann *et al.* 2008) was developed to assess both, natural and anthropogenic soils in the temperate regions. The evaluation of soils in urban areas should be the basis for the protection of high-quality soils from sealing and other degradations of soil functions. Also, urban soil evaluation is aimed to improve the quality of constructed soils.

The functionality of soils and its evaluation
Introduction of Soil functions
The term soil functions and, thus, the concept of multifunctionality of soils was introduced by Schlichting (1972). Schlichting adopted concepts established in forestry similar to the one documented by Endres (1905). The concept of soil functions was further developed by Brümer (1978) and initially adopted by the German federal state Baden-Wuerttemberg in the Soil Protection Act of the Federal State of Germany Baden-Württemberg (Umweltministerium von Baden-Württemberg 1991). Following a publication by Larson and Pierce (1994), the concept of soil functions became widespread globally. In 1998, the Federal republic of Germany introduced the Soil Protection Act of Germany (Bundesministerium der Justiz 1998). Recently, the European Union (European Commission 2006) discussed a soil protection law based on the protection of the following soil functions.

- biomass production, including agriculture and forestry
- storage, filter and transformation of nutrients, substances and water
- biodiversity pool, on the levels of habitats, species and genes
- physical and cultural environment for humans and human activities
- source for raw materials
- function as carbon pool
- archive of geological and archeological heritage

The set of soil functions differ when urban areas are the focus, specifically (Lehmann 2006):

Soil functions relevant for hazard protection in urban areas
- protection against rainstorm damages and flooding
- microbial decomposition of organic contaminants
- retention and immobilisation of inorganic contaminants

Soil functions relevant for production in urban areas
- renewable resources (clean water and air)
- plant products

Soil functions relevant for the environmental quality in urban areas
- dust capture
- carbon sequestration
- buffering of climate extremes, mainly through cooling by evaporation
- habitat for rare vegetation
- greenspace for recreational activities

Soil functions relevant for the cultural heritage of urban areas
- prehistoric and historic archives

Evaluation of the functionality of urban soils
Urban soils can be evaluated similar to natural soils if the specific properties of urban soils are considered. Most important are wider range of some parameters. Such parameters include, for example, the amount of organic matter in mineral soils, bulk density, CEC, EC and pH. In addition, features like high contents of coarse material and contamination must be included in evaluation procedures for urban soils. Table 1 provides an overview of common and rare expressions of parameters for anthropogenic urban soils.

Application of results from the evaluation of urban soils for spatial planning
For considering the functionality of soils in spatial planning, a simplification of the evaluation results (e.g., five-step scale as results of a schematic evaluation procedure for each function) and the integrated interpretation of the soil quality by experts is required. Such interpretations must place the evaluation results in the local context of ecology and planning. This is illustrated with examples in the following section, first focusing on soil water, and then on climate.

The first two examples deal with infiltration and transport of water in soils. In TUSEC the quantitative and qualitative aspect of the function "Soil as Component of the Water Cycle" is considered as well as the soil performance "Soil as Medium for Infiltration and Seepage". Soil performances are understood in TUSEC as facets of the ecological functionality of soils with direct economic value. Thus, soil performances allow to refrain from costly technical measures. Soil performances respected in TUSEC and considered particularly in urban areas are "soil as medium of infiltration and seepage".

Soil water
Two examples of recommendations basing of soil evaluation should illustrate how soil evaluation could contribute to spatial planning and constructing in points of water management:

At site I, the results of soil evaluation revealed that the projected reservoirs for the capture of precipitation will not be required. The soil capacity for absorbing precipitation in the area of the planned reservoirs even exceeds the storage volume of the reservoirs.
At site II, a building area was located on a hillside with a moderate slope gradient. There it turned out that the quantity of water which can infiltrate into the soils was calculated to be not sufficient. The reason for this wide-spread incorrect estimation is a low water permeability into the lower ground of the soils on the hillside. It was overlooked that the soil layers near the surface are often very permeable, also for lateral water flow. Such a composition of permeable and less permeable soil horizons is typical at many lanscapes with a relief. In fact, in such soils water seepage orientation is vertical only for a short distance before being diverting parallel to the hillside – so that water immediately drain down the slope to the next nearest water body.

Thus, it became obvious not only the evaluated soil, but also the surrounding soil and their relief positions as well as the proximity to a water body could be very important for the soil evaluation regarding water management. This means also that the evaluation of soils in relief areas needs a holistic approach. Only for flat areas it can be generalized that deep soils with silty texture and rich in organic matter are evaluated best.

Table 1. Common and rare properties of anthropogenic urban soils.

Characteristic	**... Common in Anthropogenic Urban Soils**	**... Rare in Anthropogenic Urban Soils**
Artefacts/ Fragments *(e.g., bricks, pottery, glass, crushed stone, industrial waste, garbage, mine spoil, mineral oil.)*	**At large portions** - in soils containing construction residues and other large artefacts *causing high water permeability* - in soils with surface or underground sealing	**None** - in soils developed from sludges and ashes - in soil from translocated natural soil material
pH	**Alkaline** - in soils containing carbonates from construction residues like plaster or concrete	**Acidic** - in soils containing sulphur from coal sulphuric acid
(Technical) Organic Carbon and Nutrients	**High** - in soils affected by accumulation of organic waste, dust and combustion residues - in soils formerly used for horticulture - in soils with subsoils containing former topsoil material	**Low in Organic Carbon** - in soils with regularly swept topsoil to keep it free from vegetation - in infertile soils **Low in nutrients** - in soils from parent material poor in nutrients
Contaminants	**High** - in soils containing combustion residues and other residues from industrial production processes	**Low** - in soils affected only by inputs of contaminants via dust deposition and rain
Bulk Density	**High** **- in the topsoil**: soils affected by mechanical forces on the surface **- in the subsoil**: soils affected by compaction through construction activities with big machinery used for excavation	**Low** - in soils affected by mechanically loosening - in soils high in organic matter - in soils containing high proportions of ashes
Soil Temperature	**High** - in city areas with increased air temperature (crucial for permafrost regions) - in soil affected by warm liquids or gases, or in neighborhood of warmed up technical cavities	**Low** - in soils affected by technical (induced) cooling and by cold water - in wet soils
Soil Moisture	**Low** - in soils affected by drainage, mostly for construction purposes	**High** - in soils affected by irrigation, by leakages, by drainage from sealed surfaces and by other fluxes of water
Age	**Young** - soils affected by frequent relocations due to construction activities	**Old** - soils situated in long time undisturbed niches in dow-town areas
Development	**Strong ex-situ** - soils built from relocated soil material from strongly developed soils, which was often deposited in layers during multiple constructions activities over longer times periods	**Diverse strong in-situ** - soils free of relocated strongly developed soil material (numerous soils from ≥ 50 years old show quite strong development, especially if they contain material of amorphic structure and material with large reactive surfaces, such as dust and ash)

Climate

Citizens suffer frequently during summer from high nighttime temperatures. Evaporation from the soil surface together with the evapotranspiration form soil grown vegetation provides a cooling effect and results in humidification of the air. Both effects make the urban climate comfortable for human health. However, the cooling effect of soils is rarely quantified. TUSEC undertakes a simple approach from rather restricted validity to quantify the cooling effect of soils expressed in $MJ*h^{-1}*m^{-2}$. The calculations are based on a modified method (from Renger and Wessolek 1996) to estimate site-specific averages for annual evaporation in Central Europe. For Germany, the cooling effect was calculated and tabulated for 70 climatically different sites and 8 classes of available field capacities. The site "Echterdingen" in Southwest Germany (mean temperature: 9.6°C, annual rainfall: 746 mm), near the airport Stuttgart with a Luvisol from Loess served as an example. The calculations for the cooling effect resulted in an available field capacity of approx. 230 l per square meter surface and 1.2 m depth for the Luvisol. The ground water table, however, is 10 m below the surface and therefore too deep to contribute to the amount of evaporated water. According to the input data (available field capacity, mean temperature and yearly rainfall) a cooling capacity of 1500 $MJ*h^{-1}*m^{-2}$ or 420 $kW*h^{-1}*m^{-2}$ was calculated for the soil volume of the Luvisol measuring $1*1*1.2$ m. This cooling effect is equal to the cooling capacity of an air conditioner used in middle sized rooms of approx. 20 m^2. Such an air conditioner consumes 1120 kWh annually whereas the Luvisol consumes no electrical energy.
As long as the available field capacity determines the climatic evaluation of soils (beneath climatic

parameters), the less compacted deep soils from silty and loamy texture rich in organic matter have to be protected with high priority. Also, the proximity of a soil to sealed areas and built-up areas increases the importance of the soil as irrigation does for enhanced evaporation.

Conclusion

The poor recognition of ecological functions of natural and anthropogenic urban soils by decision makers and spatial planners is clearly contradictory to their significance for environmental quality and hazard protection in cities. Also, the large potential of urban soils in terms of saving money based on the rational use of their functionality is in sharp contrast to the often inadequate use of soils and soil material for construction activities. This is obvious according to soil evaluation showing the high functionality especially of widespread urban soils with a high amount of organic matter. Therefore, the ecological functionality of urban soils has to be evaluated in the future with suitable methods and the evaluation results must be considered during spatial planning and construction activities

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Evaluation of rapid buffer methods to estimate pH buffer capacity of highly weathered soils from south west of Western Australia

Mike T F Wong and Kathy Wittwer

CSIRO Land and Water, Wembley, Western Australia WA 6014, Email mike.wong@csiro.au

Abstract

Information on the pH buffer capacity (pHBC) of a soil is important in the management of soil acidification and in soil monitoring. The pHBC of a soil is a key determinant of its lime requirement and of its time left to critical pH when production loss is likely. It enables the difficult to measure net acid addition rates to be determined from changes in soil pH over time or in spatially different treatments. In spite of its importance, there is an acute lack of pHBC data for soils in Australia and elsewhere. The problem is the length of time (normally >1 week) required for direct measurement of pHBC by standard incubation or titration methods and the consequence of slow measurement procedures on availability of this soil test in commercial laboratories and on cost.

Measurement of pH of highly weathered soils from the south west of Western Australia after 1 h equilibration in Mehlich, Adams and Evans and Woodruff buffers allowed us to calculate for each buffer, the soil pHBC from the change in buffer pH and the buffering capacity of the buffer solution (giving us the amount of acidity neutralised from the acid soils) and from the change in soil pH (allowing us to calculate the amount of acidity neutralised per unit soil pH change and per unit mass). Comparison buffer-based measurements of pHBC with direct measurement by standard titration method showed that all three buffers could be used to lower the time to estimate PHBC from a week to an hour. These buffer methods are therefore more easily adoptable by commercial laboratories and for routine work. The simplicity of these methods means that they could be used in the field simply with a pH meter and pH buffer solutions to determine soil pHBC. In addition, strong correlations of pHBC measured by titration and buffer methods with soil organic carbon content open the way to estimate pHBC by pedotransfer. The buffer and pedotransfer approaches to estimating pHBC should alleviate current scarcity of this important data on soils in Australia and elsewhere.

Key Words

Adams and Evans, buffer, Mehlich, organic, pHBC, pedotransfer function, titration, Woodruff

Introduction

Information on the pH buffer capacity (pHBC) of a soil is important in the management of soil acidification and in soil monitoring. The pHBC of a soil is its ability to resist pH change on addition of acidity or alkalinity. Its value determines both the amount of lime required to raise the pH of a soil layer from its initial acid condition to a near optimal pH for plant growth (lime requirement) and the time to critical pH. This is the time available under current net acid addition rate (NAAR) until the soil layer acidifies to a critical pH defined as the pH value when production losses are likely. These losses can be severe depending on crop, soil and seasonal conditions (Wong and Asseng 2007). In other scenarios, accurate values of pHBC can also be used to estimate NAAR from observed changes in soil pH over time or over spatially different treatments (Wong *et al.* 2004). This time to critical pH helps forward planning and to prioritise resource allocation and management interventions needed to address the urgency of the soil acidification problem. In spite its importance, very few pHBC measurements are available for soils in Australia and elsewhere.

The lack of data is so acute that it is currently not possible to make reliable indirect estimates of pHBC across Australia from its correlation with other more readily available surrogate soil properties such as clay and organic matter contents. Ability to develop and test this pedotransfer function approach with sufficient data is important to enable us to use existing national soil data to estimate pHBC. It is also important to allow use of in-field soil data for high spatial resolution estimates of pHBC used in precision agriculture to manage localised soil acidity (Wong *et al.* 2008). This localised soil acidity occurs due to soil textural differences and localised acidification processes such as nitrate leaching and crop removal of ash alkalinity (Wong *et al.* 2006) across the field resulting in a preference for site specific management.
Moist incubation of soil with incremental additions of calcium carbonate is a reliable method to measure pHBC but this method takes two or more weeks to complete. The quicker titration method uses suspension

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and agitation of the soil slurry to increase the rate of reaction between soil and acid/alkali. The results of this measurement are often not significantly different from those of incubation. Titration is therefore also considered a reliable way of determining pHBC (Aitken and Moody 1994; Aitken *et al.* 1990). It is completed in about a week (Aitken *et al.* 1990), which is still too slow for routine soil testing. Our aim is to address this scarcity of data by (1) assessing rapid buffer methods of measuring pHBC that could be adopted for routing soil testing and (2) assessing the correlation between pHBC and more readily available soil organic carbon content so that pHBC can also be estimated indirectly by the pedotransfer function approach.

Methods

Sixty nine acid topsoil samples with depth down to a maximum of 15 cm were collected mainly across cropping and some pasture areas south-west of Western Australia. These soil samples were chosen to cover a wide range of organic matter contents and hence a likely broad range of pHBC values. Soil organic matter content was measured by Walkley and Black wet oxidation method and pH was measured in 1:5 soil to 10 mM $CaCl_2$ suspension.

Soil pH was also measured in the supernatant of 10 g soil shaken and equilibrated for 1 h as 1:2 suspensions with the following buffer solutions (1) Mehlich buffer (Mehlich 1976) (2) 1:2 Woodruff buffer (Brown and Cisco 1984) (3) Adams and Evans buffer (Adams and Evans 1962). Soil pHBC was calculated for each buffer solution from the change in buffer pH, the buffer capacity of the buffer solution (thus giving the amount of acidity consumed from the soil) and change in soil pH (thus enabling us to calculate amount of acidity released to buffer solution per unit pH change and unit mass of soil which is in effect the pHBC of the soil sample). These buffer-derived values of pHBC were compared with direct measurement by titration. Titration was carried out using 8 g soil suspended in a ratio of 1:5 in 2 mM $CaCl_2$ and with toluene (not chloroform which reacts with NaOH) added to suppress microbial growth. Incremental amounts of either HCl and/or NaOH were added and equilibrated with occasional shaking over a period of 7 days at room temperature before measuring final pH (Aitken and Moody 1994).

Results

The soil organic carbon content ranged from 0.47 to 10.0% and pH in 10 mM $CaCl_2$ ranged from 3.9 to 5.5. Values of pHBC measured by what is regarded to be the standard titration method by which other methods are compared ranged from 0.48 in soils low in organic matter to 6.60 $cmol_c$ $(kg\ pH)^{-1}$ in soils with larger organic matter content. PHBC measured by all three buffer methods was strongly correlated with measurement by titration (Figure 1). The Mehlich buffer gave the tightest correlation and largest correlation coefficient with $r^2 = 0.87$. PHBC measured by direct titration and indirect buffer methods was strongly correlated with soil organic matter content (Figure 2). The tightest correlation was again obtained with Mehlich buffer which returned an r^2-value of 0.89. This provides a simple pedotransfer function to estimate pHBC from nationally available data for cropping and pasture areas of south west of Western Australia and for farms and fields in this region.

Conclusions

There is an acute lack of pHBC data in Australia and elsewhere due to the length of time required for its direct measurement by incubation or titration and the consequence of slow measurement procedures on cost. This work shows that buffer methods can be used lower measurement time from a week to an hour. These methods are therefore more easily adoptable by commercial laboratories and for routine work. The simplicity of these buffer methods means that they could be used in the field simply with a pH meter and pH buffer solutions to determine soil pHBC. In addition, soil organic carbon content can be used to estimate pHBC through the pedotransfer function approach. These two ways of estimating pHBC should alleviate current scarcity of this important data on soils in Australia and elsewhere.

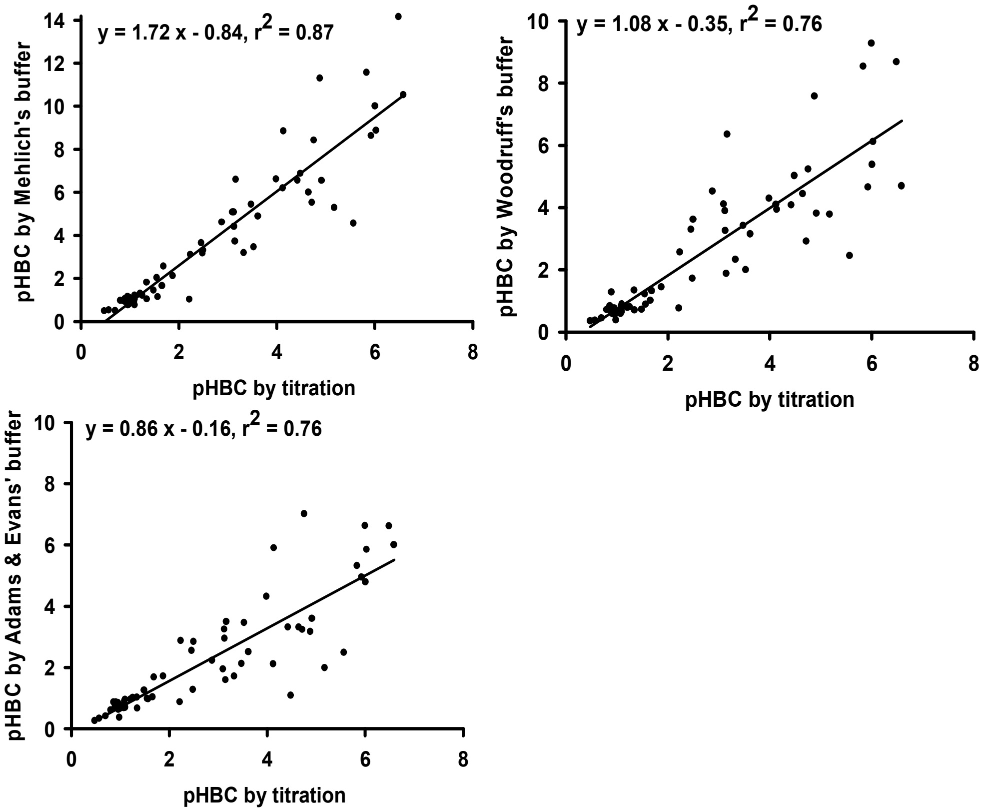

Figure 1. Regressions of pHBC measured by Mehlich buffer (Mehlich 1976), Woodruff buffer (Brown and Cisco 1984) and Adams and Evans buffer (Adams and Evans 1962) methods on pHBC measured by titration. All pHBC values are expressed as $cmol_c$ $(kg\ pH)^{-1}$.

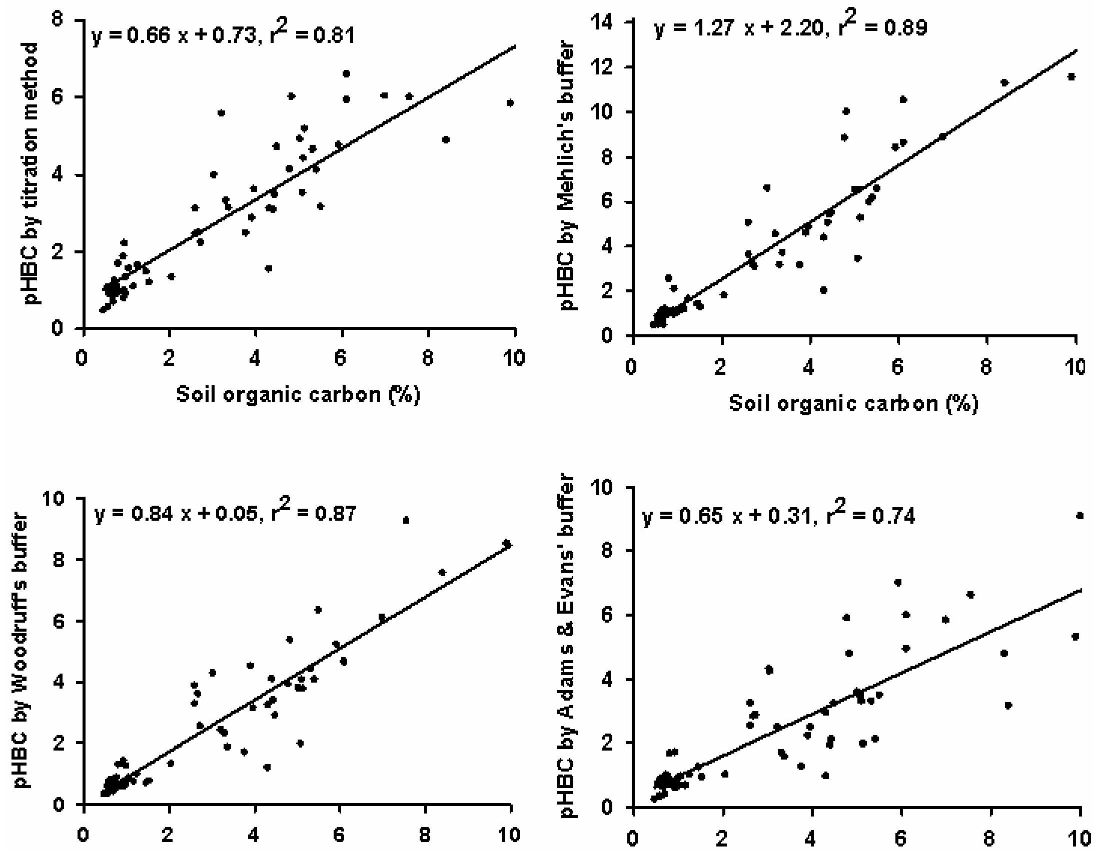

Figure 2. Regression of pHBC measured by titration and buffer methods on soil organic carbon contents. All pHBC values are expressed as $cmol_c$ $(kg\ pH)^{-1}$.

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Evaluation of surface soil condition in Tasmania, Australia

William Cotching[A] and **Darren Kidd[B]**

[A] Tasmanian Institute of Agricultural Research & CSIRO Sustainable Ecosystems, PO Box 3523 Burnie Tas. 7320, Australia, Email Bill.Cotching@utas.edu.au
[B] Department of Primary Industries, Parks, Water and Environment, Tasmania, PO Box 46, Kings Meadows, Tas. 7249, Australia, Email Darren.Kidd@dpipwe.tas.gov.au

Abstract
Soil condition information has been collected for 272 sites across Tasmania. Soil target values were developed for six key soil condition indicators, with values dependent on Soil Order and land use which allowed for evaluation of soil condition. Soil condition monitoring sites were biased to agricultural land uses, which was justified due to these land uses being more likely to result in soil degradation than conservation or native forestry. Cropping and perennial horticulture land uses had a greater proportion of sites outside targets for organic carbon and bulk density than grazing pasture and forestry. Soil pH was of concern under pasture grazing and organic cropping but most intensively used soils were within pH targets. Aggregate stabilities at many sites were outside targets under cropping and irrigated pasture. Extractable Phosphorus levels were below target for many dryland pasture sites and above target for many irrigated pasture sites.

Key Words
Targets, soil order, land use.

Introduction
Monitoring soils over the medium to long term is the only way to measure the magnitude and direction of change in soil properties arising from human and natural influences, and so monitoring is a fundamental requirement for assessment of soil sustainability. Both Soil Order and land use type are useful criteria for explaining the variability of soil properties used to measure soil condition (Sparling *et al*. 2004). An important aspect of monitoring soil condition is setting target values for different soils and land uses in order to be able to evaluate results. The soil condition evaluation and monitoring (SCEAM) project commenced in 2004 and is designed to provide the means to assess the impact of land management on soil condition and allow for improved soil management decision making and investment to improve sustainability.

Methods
Selected sites were chosen depending on where physical investigation had identified required soil orders with appropriate land use, regionally typical and spatially uniform soil profile characteristics were represented, and the land owner was cooperative (Figure 1). Twelve Soil Orders were represented and land use was divided into seven categories including conservation, dryland pasture, irrigated pasture, native forest, plantation forestry, intensive cropping and perennial horticulture. The representativeness of Soil Orders and land uses in the SCEAM data set was estimated by comparing the frequency of sampling against the mapped area of each Soil Order and land use from published information (Cotching *et al*. 2009; Bureau of Rural Sciences 2003).

Full land use history was recorded for each site. A soil pit was excavated at each site to 1.2m depth (where possible) for full description and classified to Family level. Samples were collected from each major layer within the soil with samples from any single layer bulked over a maximum 300 mm depth range. Samples were also collected by hand auger and bulked from every 2 m along a 50 m transect for both surface (0 to 75mm) and sub-surface horizons (75mm thickness cores between 75 and 300mm depth, depending on horizon depths), and chemically analysed by CSBP Wesfarmers laboratories for exchangeable cations (Ca, Mg, Na, K), exchangeable acidity, Aluminium, Hydrogen, pH (water 1:5), pH ($CaCl_2$), EC (water 1:5), Phosphorus (Colwell, Olsen), Potassium (Colwell), Boron, Copper, Iron, Manganese, Sulphur, Zinc, organic carbon (OC), total Nitrogen, ammonium and nitrate Nitrogen, and reactive Iron, (Rayment and Higginson 1992). Soil cores were collected from both depths using stainless steel cylinders (75 mm long and 75 mm in diameter) for determination of bulk density. Bulk samples were collected for determination of aggregate stability.

There is a body of knowledge already existing in Tasmania that includes a soils database held by the Department of Primary Industries Parks, Water and Environment, published information on soil properties under a range of land uses, plus expert knowledge based on experience of farmers' soil tests and trial results. This body of knowledge was drawn on, together with the results of SCEAM project to produce a set of soil targets. Soil target values were developed for six key soil condition indicators, with values dependent on soil order and land use. The selected indicators were: pH (H_2O) as an indicator of soil acidity; organic carbon as an indicator of organic matter and biological activity; Phosphorus (Olsen) as an indicator of nutrient depletion or enrichment; exchangeable Sodium, bulk density and aggregate stability as indicators of structural condition.

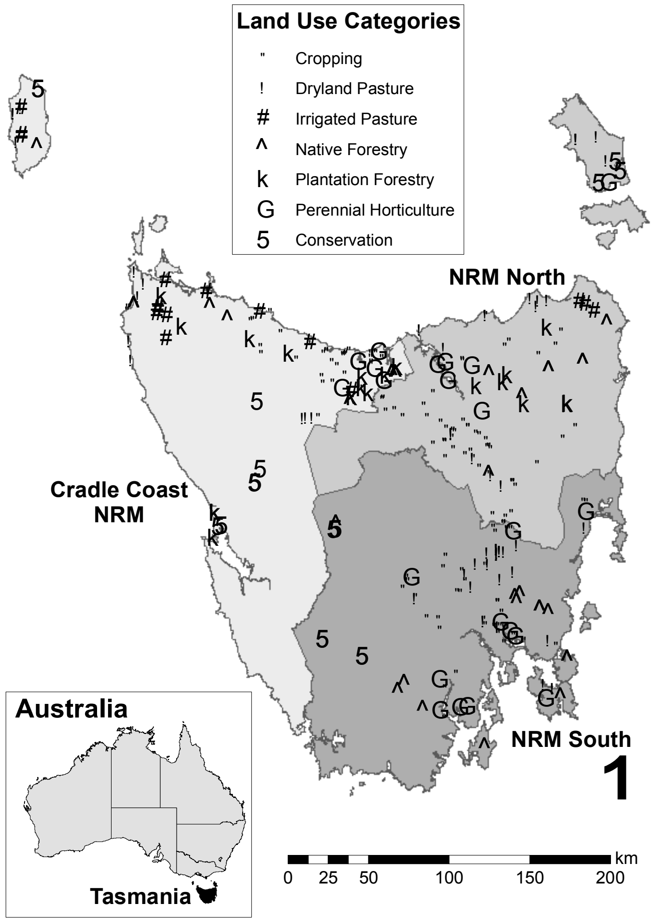

Figure 1. Site locations for soil condition evaluation and monitoring in Tasmania.

Results and discussion

The frequency of sampling in the SCEAM dataset was biased to those soil/land use combinations of concern compared with the mapped distribution of Soil Orders and land uses in Tasmania. Ferrosols, Sodosols and Vertosols were over represented whereas Kurosols, Organosols and Rudosols were under represented. The rate of sites sampled over the whole of Tasmania is one site per 24 000 ha on average, with a concentration in the northern and eastern areas (Figure 1), where agricultural land use predominates. The more intensive land uses were sampled at the expense of conservation, dryland pasture and native forestry. This is a reflection of concern over current land use trends which are for greater intensification of use and the more intensive the land use, the greater is the likelihood for soil damage.

The current targets for specific soil order/land use combinations in Tasmania (Table 1) have been set for sustainable productive agriculture but it is recognised that targets for environmental outcomes may be different. Other regions in Australia will need to develop their own targets that relate to local soil/land use/climate combinations. Some grazing sites (20 % state-wide) and organic cropping sites (23% state-wide) were outside pH targets (Table 2), but acidity has mostly been addressed by Tasmanian farmers applying locally sourced lime or dolomite. However, at some sites pH targets have been exceeded indicating that these farmers can reduce amendment inputs. The proportion of sites not meeting surface OC targets state-wide

Table 1. Targets for soil condition indicators in Tasmania.
Surface = 0-75 mm; subsurface = 75mm thick sampled between 75 mm and 300 mm

Soil property	Soil order	Land use categories	Depth*	Annual rainfall (mm)	Target value or range
Soil pH(water)	Calcarosols Chromosols Vertosols Dermosols	Pastures	Surface		5.5 – 7.0
		Cropping & Horticulture	Subsurface		5.2 – 7.0
	Ferrosols Hydrosols Kurosols Podosols Sodosols Tenosols	Forestry	Surface + subsurface		4.0 – 7.0
Organic Carbon (% w/w)	Calcarosols Chromosols Kurosols Podosols Sodosols Tenosols	All	Surface		> 2
			Subsurface		> 1
	Dermosols Ferrosols Hydrosols	Cropping & Horticulture	Surface	> 800	> 3
				< 800	> 2
			subsurface	> 800	> 3
				< 800	> 1.5
		Pastures & Forestry	Surface + subsurface	> 800	> 4
				< 800	> 2
	Vertosols	All	Surface		> 4
			Subsurface		> 3
Extractable Phosphorus (Olsen P mg/kg)	All	Pastures	Surface		23 - 28
Bulk density (Mg/m^3)	All	All	Surface + subsurface		< 1.2
Aggregate stability (% > 0.25 mm)	Ferrosols Vertosols	All	Surface + subsurface		> 70
	Calcarosols Dermosols Hydrosols	All	Surface + subsurface		> 60
	Chromosols Kurosols Podosols Sodosols Tenosols	All	Surface + subsurface		> 40
	Rudosols	All	Surface + subsurface		> 30
Exchangeable Sodium percent (ESP)	All except Organosols	All	Surface + Subsurface		< 6.0

Table 2. Proportion of sites not meeting soil condition targets in Tasmania (surface samples)

Land Use Category	pH	Organic carbon	Extractable P	Exchangeable Sodium %	Bulk density	Aggregate stability
Dryland Cropping	0	0	n/a[1]	0	0	0
Dryland Grazing/ Pasture	20	8	50	12	2	15
Intensive Cropping	4	32	n/a	7	12	28
Irrigated Pasture	6	0	56	6	6	25
Native Forest	0	17	n/a	3	3	10
Organic Cropping	23	8	n/a	8	0	38
Perennial Horticulture	5	23	n/a	0	23	19
Plantation Forestry	0	26	n/a	16	0	0
Conservation	n/a	n/a	n/a	n/a	n/a	n/a

[1] No appropriate target applies

shows that 32% of intensive cropping sites and 23% of perennial horticulture sites are below targets and potentially under stress. Forestry sites below OC targets (26%) could be due to sampling post-harvest following soil disturbance. Approximately half of the pasture sites are not meeting extractable Phosphorus targets with dryland grazing sites being below target, which is likely to be inhibiting pasture production, and irrigated pasture above target (data not shown), which could be leading to off-site nutrient enrichment in waterways. Soil sodicity (exchangeable Sodium percent) is of concern in surface soils under dryland pasture grazing (12%), particularly in the Northern NRM Region where Sodosols are concentrated. This indicates that management with gypsum amendments could give positive results. Perennial horticulture and intensive cropping failed to meet surface bulk density targets at 23% and 12% of sites state-wide respectively. Surface soil aggregate stability was below targets for organic cropping (28%), intensive cropping (28%) and irrigated pasture (25%) state-wide, particularly in the Cradle Coast NRM Region.

Conclusions

Soil condition information has been collected for 272 sites across Tasmania. Soil target values were developed for six key soil condition indicators, with values dependent on Soil Order and land use. The set targets allowed for evaluation of soil condition which may trigger responses in management or investment, but these targets are likely to be different for other regions depending on inherent soil and climate characteristics. Soil condition monitoring sites were biased to agricultural land uses, which was justified due to these land uses being more likely to result in soil degradation than conservation or native forestry. Cropping and perennial horticulture land uses had a greater proportion of surface soil samples outside targets for organic carbon and bulk density than grazing pasture and forestry. Surface soil pH was of concern under pasture grazing and organic cropping but most intensively used soils were within pH targets. Surface aggregate stabilities at many sites were outside targets under cropping and irrigated pasture indicating that cropping sites have an increased risk of erosion. Extractable Phosphorus levels were below target for many dryland pasture sites and above target for many irrigated pasture sites.

Acknowledgements

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Investigation on spatial variability of soil chemical and biochemical properties using independent sampling of pairs of locations

Flavio Fornasier[A] and Gilberto Bragato[B]

[A, B] CRA – Centro per lo Studio delle Relazioni tra Pianta e Suolo, Gorizia, Italy.
[A]Email flavio.fornasier@entecra.it, [B]Email gilberto.bragato@entecra.it

Abstract
The spatial variability of chemical and biochemical soil variables is often unknown in advance and it is usually investigated with nested sampling designs. Such designs do not prevent the chance of drawing variograms with a high nugget effect, in particular when variables with short-range spatial variability – like biochemical ones – are investigated. In the present research, we alternatively tested the sampling approach for non-ergodic variograms proposed by Brus and de Gruijter (1994), which is based on the independent selection of pairs of locations separated by increasing lag distances. The investigation was carried out in a 23-years old Sauvignon vineyard collecting 120 soil samples in 10 pairs of locations for each of the 6 selected lag distances. Samples were analysed for SOM, pH and K_2SO_4-extractable C, N, alkaline phosphatase and β-glucosidase. The sampling design we tested was effective in detecting soil variability at the vineyard scale. The shape of variograms also suggested that no spatial structure would have been obtained if we would alternatively adopt a systematic sampling design. Combined with easily measurable biochemical parameters, this sampling approach can be very useful in managing soil fertility according to a precision farming approach. In the end, all the investigated parameters but C_{extr} looked sensitive to the variation of soil thickness originated by machine levelling, showing that soil surface modifications made with heavy machinery can negatively affect soil fertility for decades.

Key Words
Spatial variability, biochemical indexes, chemical parameters, sampling design.

Introduction
The spatial variability of chemical and biochemical soil variables is often unknown in advance. It is usually investigated with nested sampling designs that do not prevent to draw variograms with a high nugget effect, in particular when variables with short-range spatial variability – like the biochemical ones – are investigated. In the present research, we alternatively tested the sampling approach for non-ergodic variograms proposed by Brus and de Gruijter (1994), which is based on the independent selection of pairs of locations separated by increasing lag distances. Our purpose was to assess the feasibility of this approach when applied to single sampling campaigns for the determination of seasonally variable biochemical parameters that, like extractable N and enzime assays, can be very useful in soil fertility management.

Methods
The investigation was carried out in a 23-years old Sauvignon vineyard of about 1 hectare located in the Friuli Venezia Giulia region, far northeast of Italy. This area has been originated by the outcrop of Eocene turbidites that display alternated layers of marls and sandstones. The soil of the surveyed vineyard, in particular, was an Aric Regosol (FAO 1998) on a topslope area that was levelled before plantation.
A total of 120 sampling locations was selected according to the design-based procedure for non-ergodic variograms proposed by Brus and de Gruijter (1994). In practice, we selected 6 lag distances – 2, 5, 10, 20, 30 and 40 m – in order to include all possible scales of variability within the size of the vineyard. Ten pairs of locations per lag were then selected on the basis of a simple random sampling design.
Soil samples were collected in August 2007 in the 2-20 cm soil layer and split in two subsamples. The first one was kept moist to determine biochemical parameters. Extractable organic C (C_{extr}) and N (N_{extr}) were determined with a Shimadzu TOC-V CSN analyser equipped with a TNC module, after extraction with 0.5 M K_2SO_4 for 30 minutes. β-glucosidase and alkaline phospatase were determined using p-nitrophenyl derivatives. The second subsample was air-dried and sieved at 2 mm for pH (potentiometric measurements in a 10 mM $CaCl_2$ solution) and soil organic matter (loss on ignition) determination.
The sampling design adopted produced an uneven distribution of observations. We then used the residual maximum likelihood (REML) approach to model variograms (Marchant and Lark 2007). Since REML modelling needs Gaussian-distributed, we transformed data with the Gaussian anamorphosis transformation

implemented in the ISATIS package (Geovariances 2000). Gaussian-transformed data were analysed and interpolated with the *geoR* library of the R statistical package (Ribeiro and Diggle 2001). Predicted data were in the end back-transformed to draw up maps in the original units of measure.

Results

Table 1 summarizes the statistics of the data. The coefficient of variation ranged between 1% on pH and 54% of N_{extr} and, apart from alkaline phosphatase and pH, variables displayed a non-Gaussian distribution.

Table 1. Summary statistics (*n* = 120)

	Min	Mean	Max	Std. Dev.	Skewness	Kurtosis
SOM (g/kg)	6.9	36.4	55.4	7.8	-0.390	4.197
C_{extr} (mg/kg)	1.02	2.05	4.34	0.59	0.857	4.515
N_{extr} (mg/kg)	0.14	1.00	2.53	0.54	0.416	2.671
pH	7.18	7.33	7.50	0.06	0.077	2.907
Phosphatase (µM p-NP/g)	16.2	77.0	130.9	25.7	-0.102	2.336
β-glucosidase (µM p-NP/g)	5.5	18.2	50.9	8.9	1.392	5.239

Table 2 reports the parameters of the models fitted to variograms of Gaussian-transformed variables. Despite the very detailed scale adopted, only N_{extr} and phosphatase showed a nugget effect lower than 50% of the total variance. As far as the scale of the spatial variability is concerned, the lowest range concerned C_{extr}, whereas SOM and N_{extr}, and phosphatase and β-glucosidase showed comparable scales of variability.

Table 2. Variogram models fitted with the REML approach.

	Nugget variance	Range (m)	Sill variance
SOM	0.609	45	0.413
C_{extr}	0.599	8	0.380
N_{extr}	0.252	57	0.895
PH	0.746	17	0.242
Phosphatase	0.525	79	0.548
β-glucosidase	0.694	91	0.385

Figure 1, in the end, shows the spatial pattern of four variables and the orthophoto of the vineyard took in 2003. The aerial photograph taken about 20 years from vineyard plantation is related to soil levelling. According to the photograph taken in the previous flight of 1975, the light-coloured areas located in the upper and in the lower-right part of the picture correspond to slightly raised field portions whose soil was partly removed by levelling. The spatial pattern of the four interpolation maps is comparable to that of the photograph. Higher pH values indicate a higher content of carbonated materials near the surface, hence the presence of a thinner soil. The other parameters display almost the same pattern of pH, suggesting a long-term effect of machine levelling on SOM and other parameters related to soil microbiological activity. This kind of information is very useful in soil fertility management, helping to modulate fertilization at a very detailed scale to decrease production variability in vineyards.

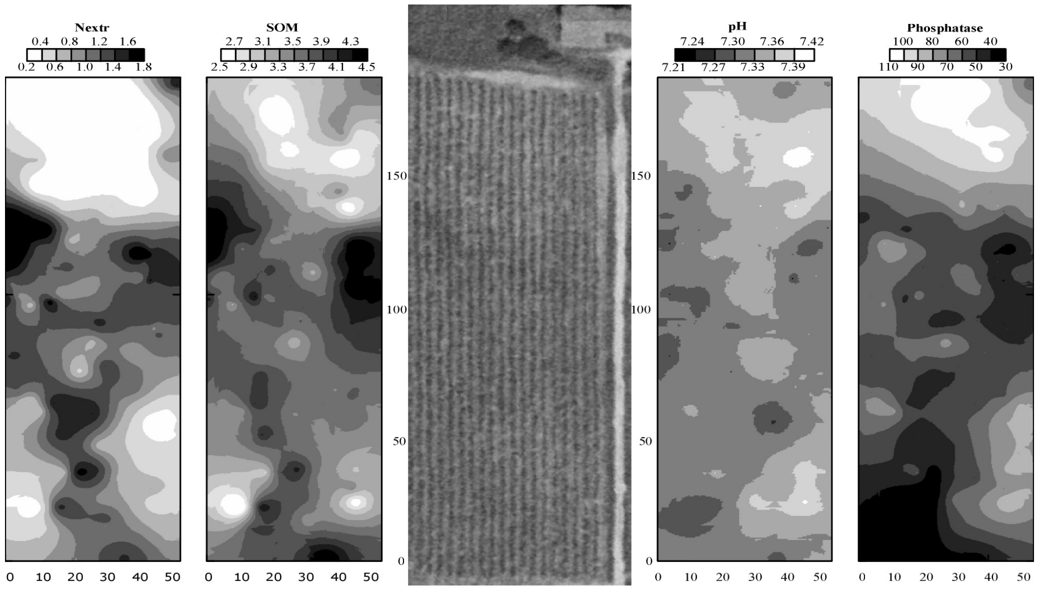

Figure 1. The 2003 orthophoto of the vineyard (in the centre) and kriging maps (left to right) of N_{extr}, SOM, pH and alkaline phosphatase.

Conclusion

The sampling design we tested was effective in detecting soil variability at the field scale of a single vineyard. The shape of variograms also suggests that no spatial structure would have been obtained with sampling distances larger than 15-20 m, i.e. those that we should have adopted to survey the same area by means of a systematic sampling design. Combined with easily measurable biochemical parameters, this sampling approach can be very useful in managing soil fertility according to a precision farming approach. In the end, all the investigated parameters but C_{extr} looked sensitive to the variation of soil thickness originated by machine levelling, showing that soil surface modifications make with heavy machinery can negatively affect soil fertility for decades.

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Land and soil controls over the spatial distribution and productivity of rubber (*Hevea brasiliensis*) in Southern India

N. Usha Nair [A], K. M. Nair[B], S. Meti[A], D.V.K. Nageswara Rao[C], Binni Chandy [A] and L.G.K. Naidu[B]

[A]Rubber Research Institute of India, Kottayam, Kerala, India 686 009, Email usha@rubberboard.org.in
[B]National Bureau of Soil Survey and Land Use Planning, Hebbal, Bangalore, India 560 024, Email nairkmn@yahoo.com
[C]Indian Grassland and Fodder Research Institute, Near Pahuj Dam, Gwalior Road, Jhansi-284 003 (INDIA)

Abstract
The primary rubber-growing area in India is the west coast of Southern India. Land and soil qualities exert considerable influence on the spatial distribution and productivity of rubber in the area. Lowlands with imperfectly drained soils and lands with elevation more than 600 meters above mean sea level were found to be unsuitable for the crop. At higher elevations lower temperatures retarded the crop growth and yield. The effect of rainfall is more in its distribution rather than the quantity and the period of soil moisture deficit significantly influences rubber productivity. The highly weathered tropical soils with strong acidic reaction, gravelly clay texture, low bases and low cation exchange capacity presented no limitation for the crop. Psamments, Usterts and Ustalfs are generally not cultivated to rubber. Hydromorphic soils (Aquepts/Aquents) are also unsuitable for the crop. High available water capacity of soils, contributed by deep solum and non-gravelly clay texture, in combination with short climatic dry period resulted in better crop yield. Soil map with soil types defined according to Soil Taxonomy together with agro-climatic maps can help identify land and soils suitable for rubber cultivation.

Key Words
Rubber-growing soils of India, soil taxonomy, soil suitability for rubber

Introduction
Rubber was introduced to the west coast of Southern India, where soil and climatic conditions were similar to original habitat (Brazil), during third quarter of 19th century and commercial plantations were established by early 20th century. The area under rubber plantations witnessed a quantum leap since 1960's in the region, driven by the demand for natural rubber. The current area under the crop in west coast of Southern India is around 5,31,455 hectares. Land and soil qualities are the primary controls over the spatial extension of the crop and its productivity, when market economy is in favour of rubber. This paper gives an account of the land and soil related controls over the spatial distribution of rubber plantations in west coast of Southern India and attempts to relate the variability in crop productivity to land and soil qualities. The insight gained can be profitability employed for strengthening the soil-site suitability evaluation criteria for rubber, a perennial crop with long gestation period to production and long productive life.

Methods
A soil map of the study area (west coast of Southern India) at the scale of 1:250K was generated through land form analysis, field soil survey, laboratory analysis and GIS processing of data to derive maps (Krishnan *et al.* 1996). The map units were association of soil families (Soil Survey Staff 1990) which were described for land form and soil qualities. A soil map at 1:50K scale for rubber- growing areas was generated in similar fashion (NBSS Staff 1999) had map units of soil series association and more detailed description of land and soil qualities. An agro-climate zones map was generated following the methodology described by FAO (1976 and 1978) and the map units were described for over head climatic parameters and length of growing period (or length of dry period) in a year reflecting soil moisture availability for crop growth (Naidu *et al.* 2009). Rubber latex yield data gathered by Rubber Research Institute of India as part of their crop monitoring program (Chandy and Sreelakshmi 2008) was organised on regional basis and used for relating productivity to land and soil qualities.

Results
Land form, elevation, climate and soil qualities were the primary determinants of the spatial extension of rubber and the productivity of the crop in the study area. The findings are presented and discussed in brief in the following sections.

Land form
Major land forms of the west coast of southern India are high hills and coastal plains. The hilly terrain has steeply sloping lands with elevation ranging from 600 to 2000 meters. The coastal plains consist of land with rolling to undulating topography interspersed by nearly level narrow valleys and low lands. The rubber growing areas are confined mainly to the rolling and undulating lands. The rubber plantations established in hilly areas with elevation more than 600 meters failed to yield rubber latex in economically viable quantity. The spatial extent of rubber plantations also excluded valleys and coastal low lands which are subjected periodic inundation by water.

Climate
The west coast of Southern India experiencing humid tropical monsoon climate with high temperature and rainfall is climatically suitable for rubber. The mean annual rainfall range from 1500 mm to 5000 mm and mean annual temperature is 27.1 °C in rubber -growing areas. Mean annual temperatures lower than 20 °C experienced in hill ranges with elevation more than 600 meters above mean sea level was found to seriously impair the productivity of rubber. Again, the rubber latex production was found to be related to the period of soil moisture availability (or its deficit) in a year.

Soils
The highly weathered soils developed under humid, tropical climate are strongly acidic, low in exchange capacity and bases, but rich in organic matter. Major soils of the study area are Ustipsamments and Tropaquepts in coastal nearly level low lands and valleys, Kandiustults, Kandihumults, Palehumults and Humitropepts on rolling to undulating lands, Haplohumults and Argiustolls on high hills and Usterts and Ustalfs in small area of upland plains. The Psamments and Aquepts exhibiting hyromorphic features are seldom used for rubber cultivation. So also are the Usterts and Ustalfs. The soils extensively used for rubber cultivation are Kandiustults, Kandihumults, Palehumults and Humitropepts. The temperature regime and mineralogy class used for defining soil family are isohyperthermic and kaolinitic respectively for the entire region. The particle size class is either clayey or clayey-skeletal. Particle size class serves as good indicators of the effective soil volume and water retention capacity. The soil map of the rubber-growing areas indicted that soil variability is confined mainly to the content of gravel, organic matter and water holding capacity.

Rubber productivity in relation to land and soil qualities
The land and soil qualities, besides their influence on the spatial distribution of rubber, affect the yield performance also. The rubber yield in region A (Figure 1) was highest. This can be attributed primarily to the non-gravelly, deep soils with high water holding capacity. Though the total rainfall is quite low (compared to other regions), it is well distributed and the dry period is minimum. The decline in yield as one moves from zone B to zone E (south to north) corresponds with the increase in the length of dry period, in the absence of significant soil variability in the same direction.

Table 1. Regional variability of soil properties, climate and rubber latex yield.

	Region A	Region B	Region C	Region D	Region E
Annual rainfall (mm)	~1500	~2500	~3000	~3500	~3500
Length of dry period	12 weeks	12 weeks	12 weeks	16 weeks	20 weeks
Soil depth (cm)	100 – 150	100-150	100 – 150	100 – 150	100 – 150
Soil texture	Non-gravelly clay	Gravelly clay	Gravelly clay	Gravelly clay	Gravelly clay
Soil organic carbon (%)	1.2	2.3	1.6	1.3	1.4
Available water capacity of soil (mm)	116	87	76	60	70
Mean dry rubber yield (kg/ha)	1451	1375	1298	1281	1141

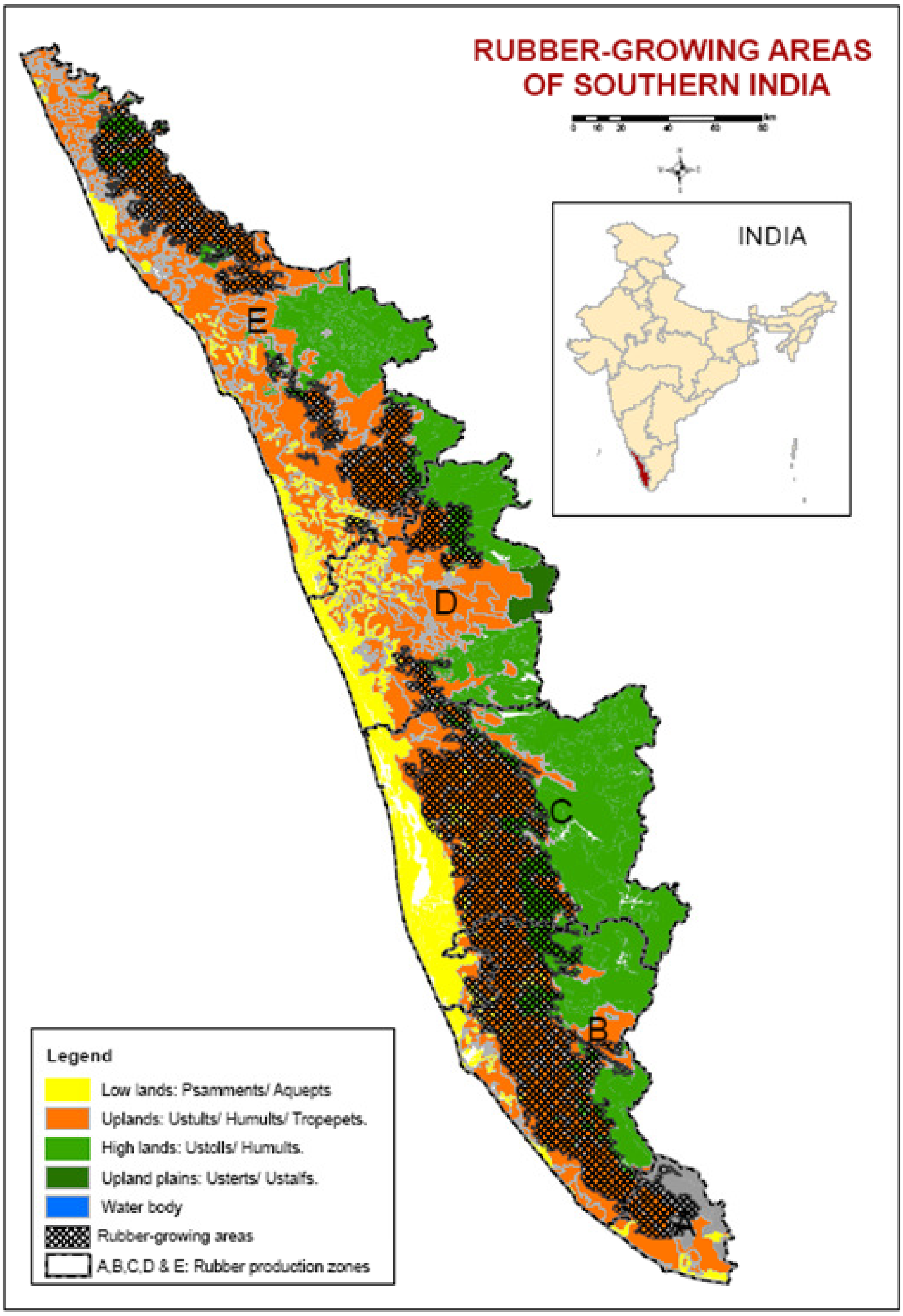

Figure 1. Spatial distribution of rubber-growing areas on a generalised landform-soil map of west coast of Southern India.

Conclusions

Tropical lands experiencing hot humid climate are eminently suitable for rubber production. The land related controls over rubber are elevation, climate and susceptibility of land to flooding. Elevation induced lower temperatures limit the suitability of land for rubber in high altitude regions of tropics. Well distributed rainfall, even when the total rainfall is only around 1500 mm, is adequate for the crop. Highly weathered, well drained tropical soils, though strongly acidic, low in bases and cation exchange capacity, were not found to limit rubber production. Soils with drainage limitations were unsuitable for rubber. Available water capacity of soils, as determined by the effective soil volume, coupled with amount and distribution of precipitation had a significant influence on productivity of the crop. Soil classification following USDA Soil

Taxonomy can be used as a primary guide for selecting areas for natural rubber production. Iso-hyperthermic temperature regime employed as a criterion for differentiating soil families according to Soil Taxonomy may be used with caution for assessing climatic suitability for rubber since the lower limit of the class (mean annual temperature of 22 °C) do not ensure year long temperature above 22 °C. Yield performance of rubber declines rapidly as the temperature goes below the value.

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Land Degradation Assessment: the LADA approach

Freddy Nachtergaele [A], Riccardo Biancalani [B], Sally Bunning [C] and Hubert George [D]

[A] Freddy Nachtergaele, Land and Water division, FAO of the UN freddy.nachtergaele@fao.org
[B] Riccardo Biancalani, Land and Water division FAO of the UN riccardo.biancalani@fao.org
[C] Sally Bunning, Land and Water division FAO of the UN sally.bunning@fao.org
[D] Hubert George, Land and Water division FAO of the UN hubert.george@fao.org

Abstract
The LADA project has prepared guidelines and manuals to describe land degradation and sustainable land management at different levels and at appropriate scales and has tested them in six countries around the globe. These methods rely on participatory approaches, field surveys and remote sensing. At the same time the project has developed a number of definitions and innovative approaches to characterize and make an inventory of land degradation and sustainable land management. The main recommendation of the project is to streamline and implement the sub-national inventories worldwide to obtain a reliable baseline for impact assessment of land degradation and sustainable management.

Key words
Land degradation, land assessment, sustainable land management, LADA.

The LADA approach
The Land Degradation Assessment in Drylands (LADA) project has as part of its objectives to assess land degradation at local, national and global scale. In order to do so, the project has developed guidelines for each assessment level.

At global level, methods were developed that evaluated long terms in trends in Net Primary Production corrected for rainfall as documented by Zhao *et al.* (2008). Also at global level, a geo-referenced inventory was made of individual indicators associated with land degradation such as slope, soil vulnerability to erosion, long term trends in droughts, biodiversity and socio-economic factors (Nachtergaele *et al*. 2009).

At (sub) national level, Liniger *et al*. (2008), provided methods and approaches to map both land degradation and sustainable land management by analyzing their status, causes and impacts in each major land use type per province within a country. The resulting database provides a wealth of information that is readily available and can be used for monitoring progress and for decision-making on land use and management interventions. A national land cover change study is also undertaken (Latham *et al.* 2008) providing information on land pressures.

At local level, McDonagh and Bunning (2009) documented a systematic inventory method on the status of the land in all its aspects (soil health, water quantity and quality, vegetation status and biodiversity). This information is complemented with local knowledge from land users and key informants on land use and management practices during the field survey and with results from semi-structured interviews of different categories of land users on the causes and impacts of land degradation at the community level.

At the same time, the project built on existing harmonized indicator descriptions developed for the Mediterranean region (Zucca *et al.* 2009) under the DESERTLINK project, to provide an information base of systematically documented indicators that can be used to characterize and evaluate land degradation status. The indicators are organized by scale of application and by their position in the DPSIR framework.

An evaluation of the key sustainable land management (SLM) measures, being used in the country and in local study areas, for the prevention and mitigation of land degradation and rehabilitation of degraded lands, is also conducted using the WOCAT approach (WOCAT 2007).

At each level the information from the various tools are brought together and analyzed to understand the main causes and drivers of degradation and the impacts on livelihoods and other ecosystems services. Finally, a review of relevant institutional and policy issues affecting land users capacities to address land degradation, is conducted through a SWOT analysis (strengths, weaknesses, opportunities and threats which completes the assessment process in each LADA country.

Hidden aspects of land degradation

This comprehensive approach needed to operate within a framework that could capture the various perspectives and processes of land degradation in a more precise way. . Moreover, it needed to take into consideration the fact that the concept of land degradation has evolved over time as illustrated by the changing definitions that have been used:

- FAO 1979: Land degradation is a process which lowers the current or potential capability of soils to produce

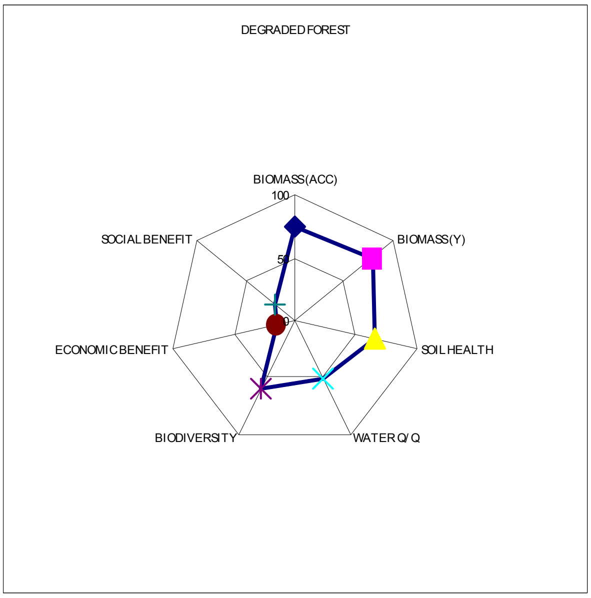
- UNEP 1992: Land degradation implies reduction of resource potential by a combination of processes acting on land.

- MEA 2005: The reduction in the capacity of the land to perform ecosystem goods, functions and services that support society and development.

- LADA 2009: The reduction in the capacity of the land to provide ecosystem goods and services and to assure its functions over a period of time for its beneficiaries..

Over the last thirty years, the object of land degradation has expanded from a focus on the soil to a focus on the ecosystem as a whole and from the narrow concept of production to the more encompassing one of the range of goods and services provided. The LADA contribution to this debate was to draw attention to the fact that it is essential to define the time period over which land degradation processes should be considered, and consequently the need to agree on a baseline against which the present state of the land should be evaluated. Indeed, one can imagine that in a garden of Eden scenario most of the land on Earth should be considered degraded at present, in relation to its pristine state, while if we only go back ten or even thirty years in time the land degradation situation may be less dramatic and more readily understood (and hence addressed). In fact, the time factor is important in order to give a framework for understanding the processes that caused the present situation. One needs to understand if the forces that created the present status are still operating, and evaluate their strength by considering the baseline at a given moment in the past. This understanding is supported by a dynamic use of the DPSIR indicators. The second aspect, by which the LADA definition of land degradation is different from previous ones, is that the role of the beneficiaries or stakeholders is fully recognized. This makes explicit the fact that a same given status of land can be considered good or bad depending on the intended use or value system of the concerned stakeholder. The land degradation situation is therefore qualified "in the eye of the beholder". To complicate the picture one should also consider that stakeholders' opinions may vary over time as a reflection of their changing interest in the land and the goods and services provided, for example, the recent attention to biofuels, climate change adaptation and mitigation and carbon sequestration. These latter aspects regarding time period and use values of beneficiaries are particularly important at local level and should form the basis of negotiation in developing locally adjusted land use plans and sustainable land management (SLM) interventions.

In order to evaluate the goods and services of the "ecosystem" a simplified scheme is proposed by LADA that reflects in accessible terms the various dimensions of land degradation. These correspond very much with the provisioning, regulating, supporting and socio-cultural services developed under the MEA (2005) but tie them down to more tangible objects of study. LADA proposes a particular focus on seven different aspects of goods and services: biomass production, yearly biomass increments, soil health, water quality and quantity, biodiversity, economic value of the land use, and social services of the land and its use. These can be represented using a spider diagram (Figure 1). Changes in these goods and services over time may occur most directly under changing land use conditions because of population pressures, external market forces (e.g. price fluctuations, social conditions of the stakeholder) or institutional measures (legislation on natural resource use, subsidies). Such changes in land use will often be reflected through a change in the shape of the resulting spider diagram (Figure 1). Differences can also be reflected between different land user groups (e.g. smallholder and large commercial farmers) or between the same land user group in two different agro-ecological and socio-economic contexts.



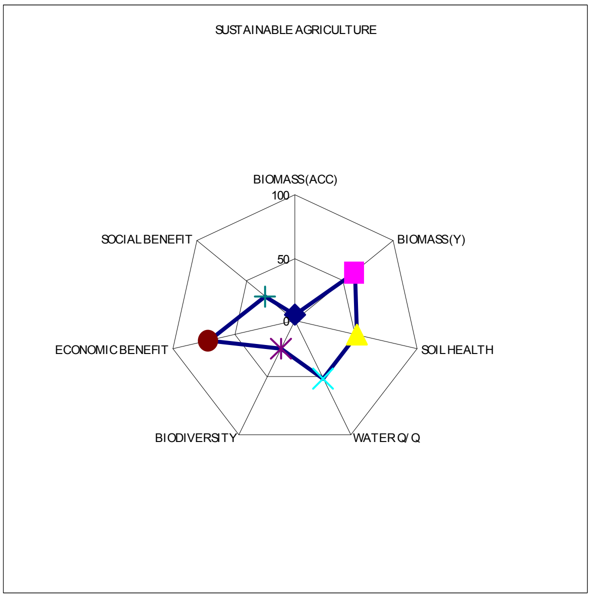


Figure 1. Goods and services evaluation in two different land use system

What is important, apart from the absolute changes in the different goods and services, as illustrated in the two diagrams above, is the fact that seldom all seven axes move in the same (positive or negative) direction when land use is changed. In other words, this reinforces the notion that land degradation is not an absolute value (as already indicated and hence emphasizing the importance of the opinion of the stakeholder in determining the effects of degradation on the goods and services and hence the value of land).

This dual aspect of subjectivity that characterizes land degradation and value is captured by LADA by drawing on the widest possible consultation with stakeholders both at (sub) national as at local level. This is the only way to generate consensus and produce balanced and reliable results.

A final issue to be discussed is the way the assessment of land degradation and improvements at different levels can be linked. The question of feedback from global to local level and vice versa was tackled early on by LADA. It was recognized that the single most important factor that drives land degradation in all its aspects is land use and intensity of management. Land use in itself is driven by socio-economic market forces and biophysical potentials and constraints of the natural resources. The recognition of land use as the unique base unit in which land degradation can be defined required that a universal system of land use inventories was developed. FAO and the World Bank had previously developed a Farming Systems inventory (Dixon *et al*. 2001) which was built upon by George and Petri (2006) to develop a national approach to land use inventory. That system, in turn, was further elaborated at a world scale using readily available global databases for defining global land use systems (Nachtergaele and Petri 2008). The principles used in this global land use system (LUS) are then applied at national level adding details on aspects of land use that are available at national level but not captured by global databases. The six LADA pilot countries, Argentina, China, Cuba, Senegal, South Africa and Tunisia, have all produced these national land use system maps for their territory at scales that vary from 1:250 000 to 1:1 000 000. The resulting LUS units are then used as the basis on which to evaluate land degradation and sustainable land management (SLM) in each of the main sub-national divisions of the countries. The national land use system units are used to identify and focus attention to priority issues requiring investigations in specific systems that deserve particular attention through local level studies. At local scale the national land use systems units are further characterized by land use types. (McDonagh and Bunning 2009) to assess and compare the effects, on-site and off-site, of specific management practices (e.g. repetitive tillage or conservation agriculture, water harvesting or irrigation) and, to the extent possible, to gauge their impacts on the key productive, ecological and socio-cultural services of relevance in the local area study area (e.g. reliable harvests, water supply, carbon and nutrient cycles). This focus on land use as the basis for assessing land degradation and improvement results in nested and scalable information from local to global level and vice versa.

Conclusions and Recommendations.
LADA has prepared guidelines to assess and monitor land degradation and sustainable land management at different levels and has tested them in six countries around the globe. These methods rely on participatory, multi-disciplinary approaches, and the combination of field surveys and remote sensing analysis.

A number of specific aspects of land degradation have been clarified by LADA. These concern the importance of temporal changes and trends to be measured against a baseline, the subjectivity of values and the need for participatory approaches to take into account the perspectives of land users and other stakeholders, and the central place of land use and its inventory in assessing land degradation.

It is recommended that the sub-national LADA/WOCAT approach to land degradation assessment is implemented through capacity building at a regional and national basis to allow a solid and complete world inventory of the status and trends of the land and thereby to improve understanding of the effects of human activities on the range of ecosystem goods and services.

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Land evaluation, key factor of successful agricultural development

Rokhaya Daba FALL[A], Ibrahima DEME[A], Papa Nékhou DIAGNE[A]

[A] Institut national de pédologie, Tel +221 33 832 65 65, Fax: +221 33 832 85 17, farodaba1@hotmail.com

Abstract
For the first time, in 2008, Senegal arable land areas have been re-estimated. In most west SAHEL countries, the arable lands for less than 20% of the national territory. This research using two methods, provides new results for arable land superficies for the Senegalese territory that are over three times larger than the previous estimations. Both methods use GIS tools and thus differ from basic maps used in the analyses: the first goes through 149 Soil and Terrain data base units while the second method considers firstly, pedoclimatic zones overlaid with hydrological data. Adequate methods and techniques are recommended for land conservation and productivity improvement, depending on identified soil quality. To refine conceptual notions and update data continuous land and water resources assessment is needed in order to guide land use in terms of soil capability.

Key Words
Soil, Arable Land, Evaluation, Geographic Information System, Agriculture.

Context
Nowadays, to successfully implement agricultural development, one should have a clear vision of sustainable land management. Rules, methods and techniques to manage land in a region or nationwide territory are specific to environmental and socioeconomic characteristics of addressed zones. Thus land evaluation is a key factor of success.

To face the global crisis several countries have been involved in defining new agricultural development politic that takes into account in one hand effects of global economic and financial difficulties, and on the other awareness of global climate change. To give a scientific basis to Senegal's new agricultural planning that aims to extend agricultural land and intensify production, authors of this research explore two methods of reevaluating available land resources available to increasing agricultural production objectives.

Materials and tools
As defined in the framework and directives for land evaluation (FAO 1976, 1984), land evaluation is "the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation". This requires matching relevant kinds of land use with land qualities, while taking local economic and social conditions into account.

Several countries have adopted means, principles, statements and rules capitalized in cited FAO documents. Two different methods have been experienced by the authors. The following table summarizes materials and tools used for both methods.

Method 1	Method 2
SN SOTER map (ISRIC, INP 2008);	morpho-pedological map (1/500000) (1985).
SN SOTER database (ISRIC&INP,2008)	pedoclimatic zones map (RDF 2009)
Isohyets Map of Senegal from 1971 to 1990 , (CSE,	Overlaid hydrographic and isohyets Maps (RDF 2009)
map of localities in Senegal (DAT)	Map of localities in Senegal (DAT)
map of senegalese protected areas (DEFCCS/CSE)	Map of senegalese protected areas (DEFCCS/CSE)
field survey (INP)	field survey (INP)
Questionnaires	Questionnaires

Methodology

A difference between the methods is constituted by the evaluation units. The first method analyzes one by one the 149 Soil and Terrain data base units elaborated in cooperation with ISRIC from the digitalized morphopedological map of Senegal (1/500 000). The second method builds new units based on underlying pedoclimatical zones and hydrological maps.

GIS tools have been used for both methods to allow their computerization in order to ensure continuing follow up. After classification of each unit, calculation of available land has been done by extraction of existing forest areas and habitation.

Method 1 Results

Category A corresponds to very suitable and irrigable land .Land belonging to category A is located in the lower valleys, watercourses, fossil valleys, basins and depressions. These soils are reserved for crops of rice and market-gardening.

Category B corresponds to suitable land without rainfall constraints. Land belonging to category B is located at sites with rainfall greater than 700 mm and has good water retention and availability.

Category C corresponds to suitable land with the possibility of water stress. Land belonging to category C is located between 400 and 700mm isohyets. Agricultural activities conducted therein may suffer water stress.

Category D corresponds to suitable land with rainfall constraints. Lands belonging to category D is subject to constraints of rainfall and requires occasional irrigation

63.10% of the Senegalese national territory consists of land suitable for agriculture. Habitat occupies 1.58% and classified forests and protected areas, 22.66% of this land. Thus 47.81% of the country is estimated to be available arable land.

Method 2 Results

By considering the possibility of the soil to provide water for agricultural use, Potential Evapo-Transpiration PET and Water Retention Soil Capacity (WRSC), the second method generate with 6 classes of arable land and one class of unsuitable inapt land. Table below gives main characteristics of classified lands.

Unsuitable land	Laterite, rocks, soil with more than 80% rocks depth limited to less than 20cm; saline soil; sulfated acid soil; alkaline soil. Non fixed dunes; sandy soils located in arid areas with high PET
class 01	Soils with particular disposition regarding their WRCS located in low PET zones generally Valleys with clay/silt soil; depressions on planes and plateau with good WRCS; plains and plateaus in high rainfall zones;
Class 02	Soil without physical and hydrological constraints include plains and plateaus in soudano-sahelian zones; sandy silt valleys in sahelo-soudanian and sahelian zones.
Class 03	Soils without main constraints located in the sahelian zone
Class 04	Starting from class 4 soils presenting constraints that can be overcome depending on possible investment or particular care. From 4 to 6 constraints are increasing but do not reach the criteria to be unsuitable. Discharge are < 80% and rock surface <30%, salinity, acidity and alkalis allow natural vegetation survival.
Class05	
Class 06	

Conclusion

Difference between first and second methods can be explained by :

1. Accuracy of the second method, which takes into account all specific possibilities to use land for any agricultural activities.

2. The first method is more general, it considers global climatic data through a unique set of three isohyets lines. It provides a global view of rainfed agriculture suitability.

Evaluation methods have to be adapted to socio-economic conditions and physical data availability. The second method represents an adequate foundation for successful agricultural development including all possible activities that can take part to solve the economic, financial and food crisis. These two fields for research should continue to be explored for the country and the regions

Land management within capability, a NSW monitoring, evaluation and reporting project

Jonathan Gray, **Greg Chapman** and Brian Murphy

NSW Department of Environment, Climate Change and Water, PO Box 3720, Parramatta, NSW 2124, AUSTRALIA
jonathan.gray@environment.nsw.gov.au

Abstract
A project was undertaken in 2007-2009 to determine the extent to which rural land was being managed within its capability, ie, sustainably, throughout NSW, Australia, as part of a monitoring, evaluation and reporting (MER) program. The intention was to provide a baseline of this parameter with which to compare with the situation in 2015 and beyond, to ascertain whether there is trend towards improvement or decline in sustainable land management throughout the state. As at May 2009, 850 representative monitoring sites had been established throughout 124 soil monitoring units (SMUs) over the state's 13 Catchment Management Authorities (CMAs). A process was developed that quantitatively compared the impact of land management actions being practiced with the capability, or physical potential, of the land to support those actions. Results were analysed to derive *Land Management within Capability (LMwC)* indices for individual and combined land degradation hazards for each SMU, CMA and the entire State. Seventy seven percent of SMUs were found to be managed unsustainably for at least one hazard. Organic carbon decline, structure decline and acidification were found to be the hazards being managed least sustainably throughout the state.

Key words
Land management, capability, sustainable, hazards, indices.

Introduction
The management of land within its physical capability is vital for the sustainable use of soil and land resources. Failure to manage land in accordance with its capability may result in a degradation of resources both on and off site, leading to a decline in natural ecosystems, agricultural productivity and infrastructure functionality. This will result in a loss of capacity of natural resource systems to carry out the functions required to support a modern society and economy. One of the 13 NRM targets set by the NSW Natural Resources Commission in this state's Monitoring, Evaluation and Reporting (MER) project was that: *by 2015 there will be an increase in the areas of land managed within its capability*. This program is aimed at ascertaining whether that target is met (Gray *et al*. in press). It complements another MER target aiming for an improvement in soil condition by 2015 (Chapman *et al*. in press).

Methods
The overall methodology involved a comparison of the estimated impact of current land management actions against the physical capability of the land and soil at a set of sample sites to derive *Land Management within Capability (LMwC)* indices. The resulting process, which has not been attempted elsewhere, is summarised in Figure 1 and more fully described in Gray *et al.* (in press).

Collection of data
The primary source of data was derived by establishing up to 100 monitoring sites within 10 prioritised Soil Monitoring Units (SMU) in each of NSW's 13 Catchment Management Authority (CMA) regions. At each monitoring site, detailed soil data was collected and the landholder interviewed about land management practices. As of May 2009, 850 sites were established and 497 landholder surveys returned. This data was supplemented by expert knowledge data systematically collected from DECCW and CMA staff.

Evaluation of capability of land at sites
The capability at each site was evaluated using the Land and Soil Capability (LSC) developed by DECCW. This scheme is an eight-class capability system that considers in detail a range of potential land degradation issues including water erosion, structure decline, acidity, organic carbon decline, salinity and others (Murphy *et al*. 2008). It uses a set of decision tables to evaluate the LSC Class for each site using available landscape, soil and climate data. Site data was applied to these tables to derive LSC values for each land degradation issue at each site.

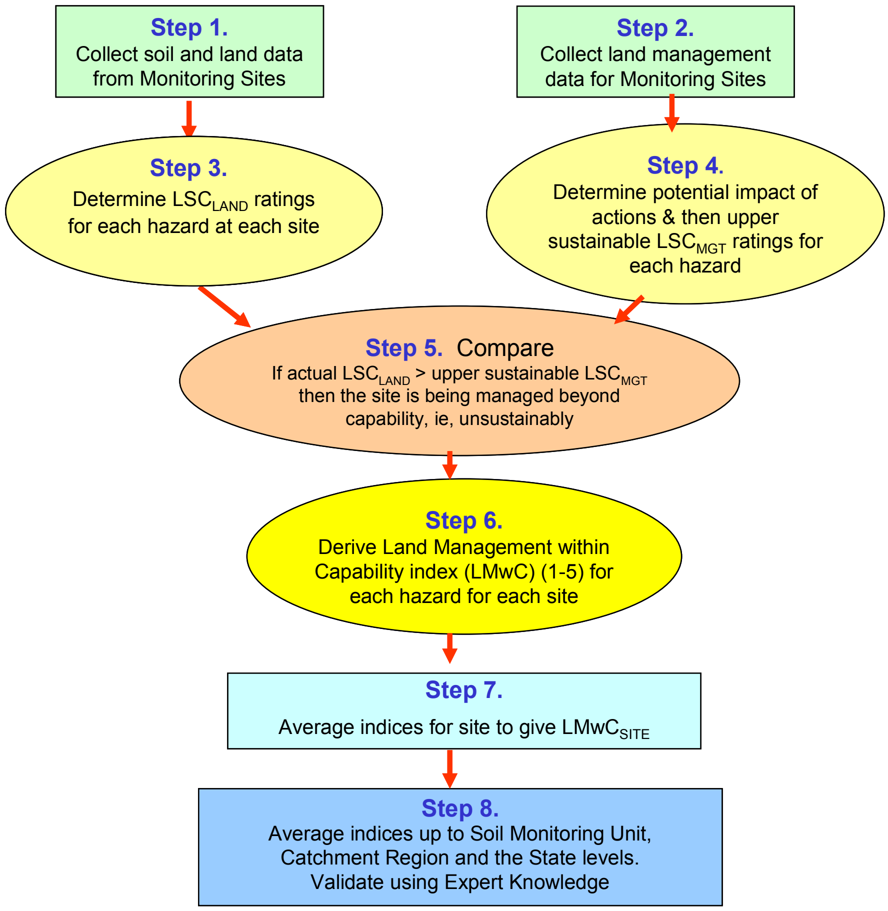

Figure 1. The land management within capability assessment process

Evaluation of land management actions at sites

A framework was developed that considers the potential impact of a range of land management actions on the individual land degradation hazards that comprise the LSC classification (eg, sheet erosion, structure decline, etc). This was developed by a working group of experts using literature values, first principles and field experience. The framework allowed individual actions at a site to be rated as having a low to very high impact on soil condition and allocated a corresponding upper sustainable LSC Class (see example in Table 1). In general, the higher the impact, the better the capability of the land must be for the activity to be practiced sustainably. The combined influence of each action was averaged out to give the "upper sustainable LSC" class for each hazard.

Table 1. Example derivation of upper sustainable LSC class

Land management practice	Specific action	Sheet erosion		Gully erosion		Wind erosion		Structure decline		Acidification	
		Impact	Upr Sust. LSC	Impact	Upr Sust. LSC	Impact	Upr Sust. LSC	Impact	Upr Sust. LSC	Impact	Upr Sust. LSC
Tillages prior to sowing	0	M-L	5	M-L	5	M-L	5	M	4	-	-
	1	M	4	M	4	M	4	VH	2	-	-
	2	H	3	H	3	H	3	EH	1	-	-
	3	VH	2	VH	2	VH	2	EH	1	-	-
	4	VH	2	VH	2	VH	2	VH	2	-	-
	>4	EH	1	EH	1	EH	1	EH	1	-	-
Length of bare fallow	0	M-L	5	M-L	5	M-L	5	M-L	5	M-L	5
(stubble & plant free) (in days)	1-7	M	4	M	4	M	4	M	4	M-L	5
	8-28	H	3	H	3	H	3	H	3	M	4
	29-90	VH	2	VH	2	VH	2	VH	2	H	3
	90-180	EH	1	EH	1	EH	1	EH	1	VH	2
	>180	EH	1	EH	1	EH	1	EH	1	VH	2

Impact	Upper sustainable LSC	Impact	Upper sustainable LSC
Extremely high (EH)	1	Moderate to low (M-L)	5
Very high (VH)	2	Low (L)	6
High (H)	3	Very low (VL)	7
Moderate (M)	4	Extremely low (EL)	8

Comparison of upper sustainable LSC for management with actual LSC of site

The upper sustainable LSC class for each land management action was compared with the actual LSC class of the land at each site. Where the upper sustainable LSC of the land management action was higher than the actual LSC of the land, the site was considered to be managed beyond its capability (see Figure 2). For example, a hot burn of stubble followed by multiple tillage with a two-way disc will have a very high impact on sheet and rill erosion, and the associated upper sustainable LSC Class for these land management actions may be 1. To carry out these actions on land which has LSC Class 3 or 4 will clearly be using the land beyond its capability.

Derivation of LMwC indices

Results for each capability issue from each site were combined across each SMU, then for the entire CMA to gain a single index, the *land management within capability (LMwC*) index for that hazard (see Figure 2). These are then combined to give an overall LMwC index for all issues for the CMA area and ultimately the State. The LMwC indices provide a broad indication of the level of sustainable land management in each CMA and across the State

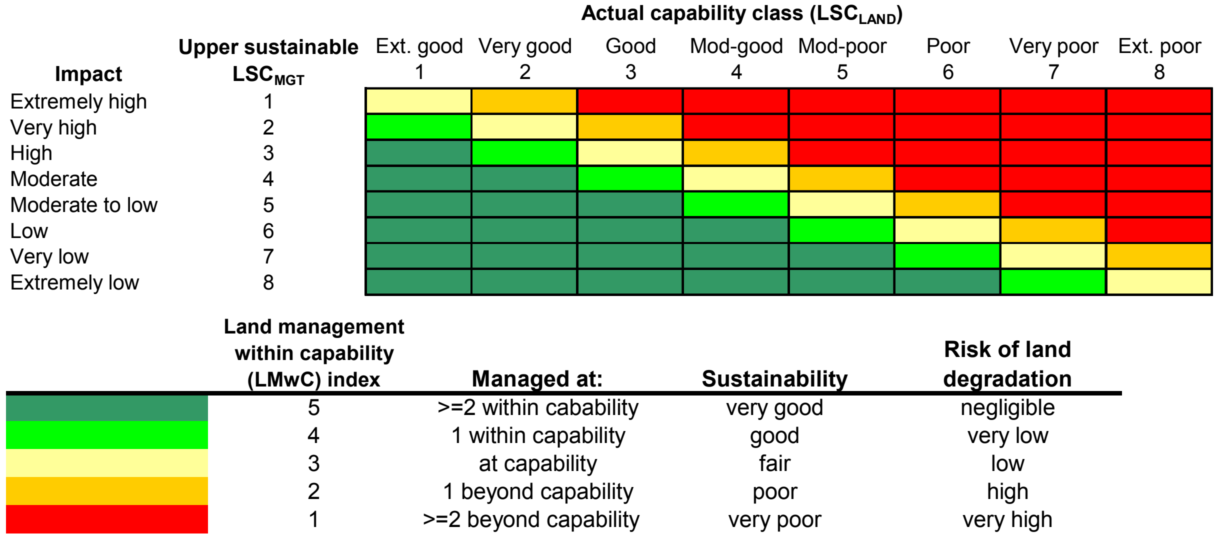

Figure 2. Derivation of LMwC indices

Results

Results from the project were prepared for each of the 13 catchment regions in *State of the Catchment* reports. Results are presented on a (i) SMU basis and (ii) land degradation hazard basis. A hypothetical example output is shown in Figure 2. On a state-wide basis it was revealed that the hazards of organic carbon decline, structure decline and acidification were being managed the least sustainably. Seventy seven percent of SMUs were found to be managed unsustainably for at least one hazard. Full results will be presented in the NSW 2009 *State of Environment* Report (NSW Government in press).

Discussion

The results provide an indication of which regions and hazards are of most concern in relation to sustainable land management across NSW. They also reveal the specific land management actions that are potentially causing the most problems and needing to be addressed. The results to date will be compared with results derived from a similar process in 2015, to ascertain whether the target of an increase in the area of the state managed within capability has been met.

There are a number of caveats on the reliability of these results that should be considered during their interpretation. These include: the incomplete data set; the relatively small sample size for state coverage, and; possible bias in the collaborating landholders towards those with more sustainable land management operations than typical landholders.

Capability Hazard	Land Management within Capability Index[a]	Range of Indices[b]	Current Pressure Trend[c]	SMUs with High Pressure (<=2.5)[d]	Data Source & Confidence[e]
Erosion - Sheet Erosion of topsoil by overland flows. Generally a consequence of insufficient ground cover.	3.2		↔	8	B & K High
Erosion - Gully Erosion of topsoil and subsoils by concentrated overland flows Generally a consequence of insufficient ground cover and changes to runoff and infiltration patterns.	2.9		↑	5, 6, 8	B & K Low
Erosion - Wind Erosion of soils by the action of wind. Generally a consequence of insufficient ground cover and inappropriate tillage practices.	4.0		↑	-	B & K Low
Acidification Trend towards increasingly acid soils, leading to reduced chemical health. A consequence of inappropriate management such as over intense use, allowing excessive leaching, over use of nitrogen fertilisers and insufficient use of lime.	2.9		↑	8, 9	B & K Medium
Organic Carbon Decline The loss of soil organic matter with resulting decline of physical and chemical condition. A consequence of over intense use with insufficient return of biomass to the soil.	2.9		↔	8, 10	B & K Low
Structure Decline Degradation of the physical structure of the soil, reducing the potential for water movement and plant growth. A consequence of practices such as over-cultivation, compaction by heavy vehicles and stock, and insufficient plant root growth.	2.7		↔	2, 3, 7, 10	B & K Low
Acid Sulfate Soils Mismanagement can lead to release of highly acid waters into the ecosystem. This can arise from the exposure of buried potential ASS layers to oxygen such as from lowering of watertable by drainage.	3.0		↔	-	B & K Medium
Salinity/Water logging Build up of salt or saturated soils on ground surface. A consequence of rising groundwater tables following a reduction of deep rooted perennial plants.	3.2		↓	7, 9, 10	B & K High
Overall Index : Catchment	3.1				
State	3.0				

a Land Management within Capability (LMwC) Index

4.6 – 5.0	Very low	Very low pressures on sustainable land management, negligible risk of degradation and probable improvement of soil and land resources.
3.6 – 4.5	Low	Low pressures on sustainable land management, very low risk of degradation to soil and land resources.
2.6 – 3.5	Moderate	Moderate pressures on sustainable land management, low risk of degradation to soil and land resources.
1.6 – 2.5	High	High pressures on land management relative to capability, high risk of degradation to soil and land resources
<1.5	Very high	Very high pressures on land management relative to capability, very high risk of degradation to soil and land resources
	No data	Not included for change monitoring. Information may be available in support documents

Figure 2: LMwC in an example region – by hazard

The information is expected to help guide Catchment Management Authorities and other NSW land management agencies in natural resource management decision making, for example in allocating resources and designing intervention strategies and programs. The concept of using land and soil capability assessments to guide land management practices has the potential to be expanded and significantly contribute to sustainable land management across the state.

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Mapping and characterization of boreal acid sulfate soils

Peter Österholm[A], Peter Edén[B], Annu Martinkauppi[B], Amélie Beucher[A], Markku Yli-Halla[C] and Jaakko Auri[B]

[A]Department of Geology, Åbo Akademi University, Finland, Email posterho@abo.fi
[B]Geological Survey of Finland, Finland, Email peter.eden@gtk.fi
[C]Department of Applied Chemistry and Microbiology, Helsinki University, Finland, Email markku.yli-halla@helsinki.fi

Abstract
Finland has the largest occurrence of acid sulfate soils (AS soils) in Europe. Due to their severe effects on coastal waters, there is a great demand for localizing hot spot areas, i.e. areas where preventive/mitigation measures are needed most. Thus, the Geological Survey of Finland has recently initiated a project on mapping AS soils in Finland. The work is demanding and therefore screening techniques are needed in order to narrow down areas of interest. In this work, we demonstrate the use of such techniques using Quaternary, geophysical and elevation maps prior to conventional soil mapping, and conclude that a broader concept of criteria than that of Soil Taxonomy and WRB is needed in order to enable appropriate characterization of Boreal AS soils.

Key Words
Acidity, aeroeloctromagnetic map, risk areas, mitigation, Finland.

Introduction
During the Holocene Epoch large areas of sulfide-bearing sediments have been deposited under reducing conditions on the bottom of the former and current Baltic Sea between Finland and Sweden. Because of the rapid postglacial rebound (today up to 8 mm/a) in the area, a large portion of these sediments have been raised up to 100 m above current sea level. Due to reclamation, the upper 1-2 meters have generally been oxidized into acid sulfate soils (minimum pH 3-4), giving Finland the largest known occurrence of acid sulfate soils in Europe, roughly 1000 km^2 using Soil Taxonomy criteria (Yli-Halla *et al*. 1999). It is well documented that these soils leach huge amounts of metals into watercourses (Österholm and Åström 2004), and for several heavy metals the amounts exceed the total metal discharge in effluents from the entire Finnish industry (Sundström *et al*. 2002) causing severe damage on the ecology.

Mapping of AS soils in Finland has been conducted by conventional soil sampling and subsequent soil-pH measurements (Palko 1994; Figure 1). However, the criteria for designating soils as AS soils has been rather inappropriate (commonly soil pH < 5 and > 100 mg SO4-S per dm^3), not distinguishing hot spot areas and leading to a gross overestimation of the total area of AS soils in Finland (c. 3000 km^2), as compared to if the criteria in Soil Taxonomy or the FAO/UNESCO systems had been used (Yli-Halla *et al*. 1999). Nevertheless, due to previous work, we know in broad outline where AS soils are expected to be found; in general, they are found < 50 m above current sea level with local occurrences from the northernmost to the southernmost coastal areas, and largest occurrences are located in Midwestern Finland.

Due to large scale fish kills caused by AS soils along the coast in 2006 and because of the EU Water Frame Directive calling for good ecological and chemical status in surface waters by 2015, the demand for actions preventing environmental pollution by AS soils has accentuated recently. Preventive techniques that minimize oxidation of sulfidic horizons and reduce flow peaks are the most obvious measures required. Thus, there is currently also a great demand on a new relatively detailed risk map on AS soils, enabling measures to be tailored and taken for the strategically important hot spot AS soil areas. To meet these demands, a consortium led by the Geological Survey of Finland (GTK) has been formed in order to create a nationwide AS soil map. Similar to previous mapping programs, conventional soil sampling will be conducted. However, different screening techniques will be developed and used in order to narrow down areas of interest. Such techniques will involve processing of available landscape data in GIS (including available elevation, land form, Quaternary, bedrock and (aero)geophysical data) and the use of indicator variables in recipient waters (pH, electric conductivity, sulfate and metals). Below, we demonstrate the use of such techniques using Quaternary, geophysical and elevation maps prior to conventional soil mapping.

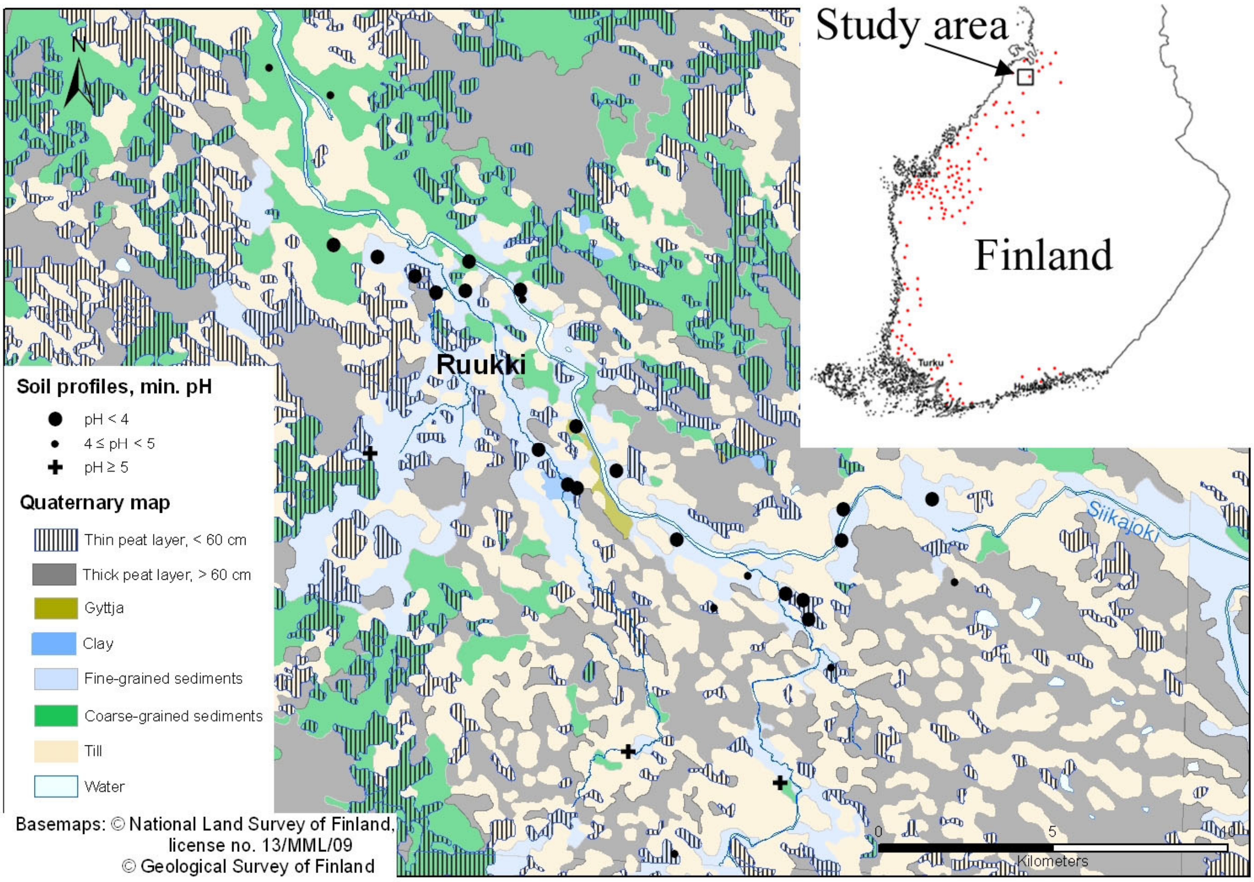

Figure 1. Quaternary map (Geological Survey of Finland, in preparation) for the upper meter of soil and minimum pH for selected soil profiles in the Siikajoki River catchment. Location of the study area and occurrence of AS soils (dots) according to Palko (1994) are presented in the upper right.

Material and methods

The study area (c. 565 km^2) is located in the Siikajoki River catchment in the northern part of the Finnish ASS province (Figure 1). The bedrock in the area is eroded to a peneplain dominated by mica gneiss with intrusions of porfyritic granite and, according to aeromagnetic maps, some layers of black schists occur in the area. The average thickness of Quaternary deposits overlying the crystalline bedrock is about 10 m and they consist of glacial till, reworked glaciofluvial sands, and postglacial alluvial, marine, and littoral sediments. Large areas are covered by mires that have developed on topographic lows after glacial isostacy induced marine regression. The map of Quaternary deposits (1:200 000) used in this study, describing the soil material distribution and textures for the topmost one meter, is still in process at GTK and will be published by the end of 2009. Till (35%) is the most dominant soil type in the study area followed by peat (31%), coarse-grained- (22%; D50 > 0.06 mm) and fine-grained deposits (11 %; D50 0.002-0.06 mm). Clay (D30 < 0,002 mm) and gyttja (clay with loss on ignition > 2%) comprise only 0.4 % of the area.

GTK measured aeroeloctromagnetic data (AEM) at a height of 30-40 m, line spacing of 200 m and measurements for each 12.5 m at one frequency of 3.1 kHz in the Siikajoki area in 1983. The AEM data reflects the electric conductivity of soil material and bedrock down to several tens of meters. Fine-grained sediments, and, in particular, sulfide-bearing sediments having high contents of soluble salts, are expected to give strong AEM anomalies (Vanhala *et al*. 2004). On basis of the electric conductivity, an apparent resistivity map (the inverse of conductivity) with a resolution of 50 x 50 m was compiled. In order to identify areas where AS soils are likely to be found prior to soil sampling, we compared bedrock, Quaternary, aerogeophysical and elevation data and when possible pH and electric conductivity in recipient waters. Areas which had a low resistivity, fine grained sediments, large low-relief fields with low pH and high electric conductivity in recipient waters were prioritized (Table 1). Areas with till deposits were excluded as they are glacigenic and lack underlying marine sediments.

Altogether, 48 soil profiles in the Siikajoki River catchment were sampled within the study area with a core sampler down to 3 meters and samples were taken for each 20 cm. Within 24 hours, soil pH was measured by inserting a pH-electrode directly into the soil material, after some deionized water had been added to allow proper contact between the electrode and soil material. Profiles with a minimum pH < 4 had underlying black parent sediment due to monosulfides (typical for Finnish AS soils; Boman *et al.* 2008) and were, thus, considered AS soils. For the purpose of this study, potential overrepresentation of certain high priority areas was reduced by inserting a grid of 1 km^2 squares over the study area. Only the profile closest to the middle of the square was chosen. However, profiles in the same square, that were located on different types of soil deposits (according to the Quaternary map) and had a resistivity difference inferior to 100 ohm-m, were included, giving a total number of 38 profiles in the study area (Figure 1).

Table 1. Relative frequency of minimum pH, starting depth (SD) for horizons with a pH < 4 and resistivity in the selected sites (n = 38) in the study area.

	Total	pH<4	pH 4-5	pH≥5	SD	Resistivity (ohm-m)		
	n	%	%	%	m	min	med	max
Fine-grained	16	69	19	13	1,1	40	186	844
Fine-grained + peat <60 cm	9	44	44	11	1.1	79	152	1950
Coarse-grained	7	29	71	0	1.3	142	829	2202
Thick peat layer (≥60cm)	4	50	50	0	0.6	120	548	878
Clay	1	100	0	0	0.9		219	
Gyttja	1	100	0	0	0.7		1913	
Total	38	55	37	8	1.0	40	383	2202

Results and discussion

In the selected sites (n=38), AS soils were frequently found in all types of soil deposit areas indicated on the Quaternary map (Figure 1 and Table 1). They were particularly abundant on fine grained sediments (typically former marine sediments) and least abundant on coarse grained soil materials (Table 1). On the basis of pH measurements, only about 10% of the sites could be excluded as being “harmless” (pH ≥ 5) without further analysis (e.g. incubation). While the proportion of AS soils in the area is unknown, it is abundantly clear from the recipient river water quality (Beucher, unpublished results) that it is far lower (probably in the order of 5% or less similar to other rivers of this size) than that indicated by the selected soil profiles (55%; Figure 1). Consequently, while screening techniques are not yet fully developed, the results indicate that they can be used to narrow down areas of interest significantly. Nevertheless, it is notable that later preliminary results (not presented in this work) indicate that compared to other sections of the river catchment; the present study area seems to have a relatively high abundance of AS soils. Thus, care needs to be taken not to over-emphasize the seemingly remarkable results of this study (Figure 1).

The fine grained sediments on the Quaternary map exhibited a significantly lower resistivity than corresponding coarse grained soil materials (Mann-Whitney test of medians at p=0.1; Table 1). A correlation between minimum pH and resistivity was only found for areas indicated as coarse grained soil materials on the Quaternary map (Spearman correlation: 0.85 at p=0.05); in indicated coarse-grained areas. AS soils (2 profiles) were found in sites with resistivity values < 300 ohm-m. Confirmed by field observations, i.e. fine grained sediments below 1 m and the lower starting depth of the pH < 4 horizon (Table 1), this phenomena is explained by the occurrence of relatively deep fine grained sediments (causing low resistivity) overlaid by coarser sediments. Consequently, in the study area, the AEM map seems to be a useful complement to the Quaternary map in order to find such risk areas.

Owing to deep drainage and some soil characteristics, we cannot restrict us to the criteria of Sulfaquepts or sulfic subgroups, as defined in Soil Taxonomy (Soil Survey Staff 1999), or particularly those of the WRB system (FAO 2006), when mapping acid sulfate soils of Finland. These systems require that the typical characteristics occur within 1.5 m or 1.0 m of soil surface, respectively. As also noted in this study, sulfidic materials in our agricultural soils are often covered with soil materials that have not been sulfidic. The depth of the sulfides together with humid boreal climate, retards the oxidation, and these soils most often do not have sulfuric/thionic horizons (pH ≤ 3.5), the minimum pH being in the range of 3.5-4.0. However, owing to deep artificial drainage and intensive evapotranspiration, sulfidic materials down to at least 2.5 m are periodically oxidized (Österholm and Åström 2002; Joukainen and Yli-Halla 2003). Being formed in non-calcareous parent materials, the total S requirement of 0.75% for sulfidic materials in the WRB system is too high, 0.2% being more appropriate. Thus, the stringent Soil Taxonomy and WRB criteria for acid sulfate soils can be embedded in the national mapping, but we need to use a broader concept for sulfidic materials and particularly for the depth of occurrence of the relevant characteristics in order to properly identify these soils.

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Measurement of land-use effects on soil carbon and related properties for soil monitoring: a study on two soil landscapes of northern New South Wales, Australia

Brian Wilson[A,D], Phoebe Barnes[B], Subhadip Ghosh[B], Terry Koen[C] and Dacre King[A]

[A]NSW Department of Environment, Climate Change & Water, Armidale, NSW 2350, Auatralia.
[B]School of Environmental and Rural Sciences, University of New England, Armidale, NSW 2351, Australia.
[C]NSW Department of Environment, Climate Change and Water, PO Box 445, Cowra, NSW 2794, Australia.
[D]Corresponding author. Email Brian.Wilson@environment .nsw.gov.au

Abstract
In Australia, and internationally, there is a growing need for information relating to soil condition, its current status, and the nature and direction of change in response to management pressures. Monitoring is therefore being promoted regionally, nationally and internationally to assess and evaluate soil condition for the purposes of reporting and prioritisation of funding for natural resource management. We present a dataset designed to assess differences in carbon and related soil properties across a range of land-use types within a basalt and granite landscape of northern NSW generated through the NSW Statewide Soil Monitoring Program. Clear and significant differences were detected between land-use types for the various soil properties determined but these effects were restricted to the near-surface soil layers (0-5cm and 5-10cm). Soil properties between the other, non-woodland land-use types were largely similar apart from a modest C increase but increased soil acidity under improved pasture. Woodland soils had larger quantities of C (T/ha corrected for equivalent mass) than any other land-use. Results from this work are being used to inform the further development the NSW State-wide Soil Monitoring Program and to populate the NSW soil carbon matrix and soil carbon models for application across the State.

Introduction
In Australia, and internationally, there is a growing need for information relating to soil condition, its current status, and the nature and direction of change in response to management pressures. This need has attained particular urgency with respect to soil carbon due to the growing perception that soil carbon sequestration might offer the potential to offset greenhouse gas (GHG) emissions. Monitoring is now being promoted regionally (Chapman *et al.* 2009), nationally (McKenzie and Dixon 2006) and internationally (e.g. Wang *et al.* 1995, Jones *et al.* 2008) to assess and evaluate soil condition for the purposes of reporting, and to prioritise investment in natural resource management. The concepts and definitions of soil health, quality and condition have been widely discussed in the scientific literature (e.g. Doran 1996, Karlen *et al.* 1997) but no consensus has yet been reached regarding the suite of soil properties that is universally appropriate to define and evaluate change in any or all of these. Most broad-scale monitoring programs that have been proposed identify soil carbon as a key "headline" indicator alongside a number of other soil properties that can be used to detect change and trend in soil condition (e.g. McKenzie *et al.* 2002, Jones *et al.* 2008). In Australia, for example, soil C and pH have been selected as key indicators of soil condition for the purposes of national soil monitoring (McKenzie and Dixon 2006) while other, regionally specific datasets have been identified in NSW (e.g. Wilson *et al.* 2008). A great deal of information currently exists in the scientific literature regarding the impact of specific management practices on soil properties in various regions of Australia (Greenwood and McKenzie 2001, Zhang *et al.* 2007 etc.). However, these studies have employed a range of methodological approaches and examined a wide range of soil properties and often single land-use systems. Here we sought to quantify land-use imposed differences in a defined set of soil indicators (bulk density, pH, carbon and nitrogen: after Wilson *et al.* 2008) in this region. We present a dataset designed to accurately and verifiably account for differences in the selected soil properties under different land-use types. The dataset presented was part of the provisional 'baseline' data layer gathered under the NSW Statewide Land and Soil Condition Monitoring Program.

Methods
Two study areas were located on the Northern Tablelands of NSW in SE Australia on Tertiary Basalt and Permian Granodiorite (Granite) around the townships of Guyra & Uralla respectively. The soils of these selected geological types were Red and Black Ferrosols and Yellow Chromosols/Kandosols (Isbell 2002) and have been grouped to form the Northern Tablelands Basalt and Bundarra Granite Soil Monitoring Units,

for the purposes of state-wide soil condition monitoring. The altitude across the region is approximately 1000m and has a temperate climate with a mean annual rainfall of 880mm which is summer dominant (i.e. total rainfall 108.3mm in January and 56.1mm in July). Maximum mean monthly temperatures in January are < 30ºC for all of the selected locations. Mean monthly minimum temperature is < 0ºC across the sample area, with frosts common from April to September.

Site Selection
Five 'site clusters' were established on privately owned farms across each study area. Each site cluster consisted of four 'treatments': i) a cultivation paddock, ii) improved pasture, iii) unimproved native grass, and iv) remnant woodland. Each of the individual treatments was in an adjacent paddock located on common soil type, landscape position, aspect and slope angle. At one property no improved pasture site was available so the design was not wholly balanced. Each treatment within a cluster was a maximum of 500m from the other treatments.

Soil Sampling
To measure differences in selected soil properties between land-use types, 10 soil cores were collected from each treatment at each site cluster. These 10 soil cores were spatially arranged within each 25 x 25 m sample plot (after Chapman *et al.* 2009), using a random, 'latin square' sampling design. Soils were sampled at a random location within the 10 selected 2.5 x 2.5 m cells using a manual coring device of 50mm diameter, driven to a depth of 30cm. The soil core was sub-divided into discrete depth increments (0-5cm, 5-10cm, 10-20cm and 20-30cm depths) in order to detect change with increasing soil depth. This sampling approach provided samples of known volume which allowed for the subsequent determination of bulk density for each individual sample. At a limited number of sample points, rock was encountered and the 20-30cm depth increment could not be sampled. Soil samples were stored in cool (< 5ºC) dark conditions until they could be processed. Samples were dried at 40ºC for 48 hours and then crushed to pass a < 2 mm sieve. Bulk density was determined on each individual sample. Each individual sample was then analysed for pH (1:5 $CaCl_2$) and Total Carbon and Nitrogen using LECO Dry Combustion method at the Environmental Analysis Laboratory, Southern Cross University, Lismore.

Statistical Analysis
For each geology, data collected from each treatment at each site (25x25m sample area) were analysed using a repeated measures analysis of variance. Since depth observations were taken at non-equally spaced intervals (0-5, 5-10, 10-20, 20-30cm), a power model was used to investigate the correlation of the residuals as being dependent upon the distance between depths calculated from their midpoints (2.5, 7.5, 15, 25cm). Significance of the fixed effects of Land Use, Depth and their interaction was examined using approximate F statistics. Differences between total carbon density (t/ha) was determined using one-way ANOVA and post-hoc lsd analysis ($P<0.05$).

Results
For both geological types, soil properties differed between the four land-use types examined (Table 1). When all the data for all sites, land-uses and soil depths were considered, a significant land-use effect was found only for soil bulk density with woodland bulk densities being significantly lower at all soil depths compared with the other land-use types. No significant main-order land-use effect was observed for soil pH, carbon and nitrogen.

The magnitude of the various soil properties determined on the basalt and granite soils differed but the relative patterns between lad-uses within each geological type were consistent. All soil properties determined showed a significant depth effect indicating that soil properties differed significantly between the soil depths sampled. Bulk density was typically lower in the surface soil layers compared with deeper soils. Soil pH had significantly lower values in the 5-10cm and 10-20cm layers compared with other soil layers across all land-uses sampled while carbon and nitrogen both declined significantly with increasing soil depth. A strongly significant land-use.depth interaction was also found for all soil properties determined, indicating different depth profile characteristics between land-uses. Examination of the depth distribution of soil properties indicated that soil pH was significantly lower at all soil depths under improved pasture compared with all other land-uses on both geologies. For carbon however, woodland had significantly higher values in the surface layers (0-5cm and 5-10cm) compared with all other land-uses ($P<0.05$ using LSD post-hoc). In the 0-5cm layer, the improved and unimproved pasture sites had similar carbon levels but both were larger

Table 1. Mean values of soil properties for each land-use type.

	Soil Depth (cm)	Bulk Density (T/m^3)		pH		Carbon (%)		Nitrogen (%)	
		Basalt	Granite	Basalt	Granite	Basalt	Granite	Basalt	Granite
Cultivation	0-5	1.31	1.39	5.17	5.07	2.81	1.58	0.22	0.11
	5-10	1.47	1.54	5.12	4.95	2.05	0.98	0.16	0.07
	10-20	1.40	1.64	5.11	4.98	1.40	0.47	0.10	0.03
	20-30	1.39	1.76	5.22	5.05	1.24	0.32	0.08	0.02
Improved pasture	0-5	1.09	1.47	4.91	4.94	3.77	1.99	0.31	0.13
	5-10	1.42	1.52	4.80	4.88	1.97	0.87	0.16	0.05
	10-20	1.42	1.64	4.99	4.96	1.31	0.51	0.10	0.02
	20-30	1.42	1.77	5.15	5.05	1.05	0.28	0.08	0.01
Unimproved pasture	0-5	1.13	1.30	5.22	5.07	3.54	2.03	0.25	0.11
	5-10	1.46	1.53	5.12	4.98	1.83	0.91	0.12	0.04
	10-20	1.34	1.59	5.17	5.02	1.16	0.45	0.07	0.02
	20-30	1.54	1.71	5.23	5.06	0.77	0.40	0.04	0.01
Woodland	0-5	0.83	1.18	5.19	5.13	6.90	2.72	0.39	0.12
	5-10	1.21	1.42	5.09	5.04	3.22	1.20	0.20	0.06
	10-20	1.15	1.46	5.11	4.93	1.70	0.67	0.11	0.02
	20-30	1.38	1.55	5.15	4.82	1.53	0.49	0.08	0.02

than the cultivation land-use. On both basalt and granite, woodland soils also had significantly larger nitrogen content compared with all other land-uses at 0-5cm. Below these depths however, no significant difference existed between the land-uses except for a slight but significantly ($P<0.05$) lower carbon and nitrogen concentration under unimproved pasture at 20-30cm.

Soil carbon densities (to 30cm deep) were also calculated for each land-use across the two study areas using the measured percentage carbon profiles and associated bulk densities of the individual soil samples collected from the various land-uses. In order to compare carbon densities between land-uses, it is now generally considered appropriate to calculate carbon densities between different land-uses expressed as an equivalent soil mass to 30cm depth. Again, the magnitude of values differed between basalt and granite but trends were consistent between the two geologies. For calculated carbon densities in the soils studied, woodland had a larger quantity of soil carbon to 30cm depth compared with unimproved pasture only. However, when carbon density was expressed on an equivalent mass basis, woodland carbon density was significantly higher than all other land-uses but there was still no significant difference in carbon density between the other land-uses.

Discussion

A number of significant patterns and trends were found in the data from the various land-use types and sites across the Northern Tablelands Basalts and Bundarra Granites. Soil BD had a significant land-use effect and was significantly lower under woodland compared with all other land-use types. This is a common finding in this region and is indicative of generally higher organic matter contents and soil porosity under trees compared with other land-uses (Young *et al.* 2005, Wilson *et al.* 2008). For all soil properties however, the differences between land-uses, were restricted to the surface soil layers. Differences between land-uses for the various soil properties diminished with soil depth and by 20-30cm depth, differences between land-uses was undetectable. This result confirms the findings of other work from the region previously reported in Young *et al.* (2005) and Wilson *et al.* (2008). Where differences between land-uses were found, woodland had higher pH, carbon and nitrogen contents and lower BD compared with all other land-use types. Much of the woodland within the study area was cleared during the late eighteenth and early nineteenth centuries in order to develop land for agriculture (Reid *et al.* 1997) and the surviving woodland in the region therefore represents little modified and minimally managed sites by comparison with the remainder of the cleared landscape. The consistently higher concentration of carbon, nitrogen and pH of these sites might therefore provide an insight into the potential pre-clearing soil condition in the region and indicate the value of this land-use as a 'reference' against which other soils and land-uses might be compared.

Soil properties between the other, non-woodland land-use types were largely similar apart from the very strong acidity under improved pasture on both geologies. This was particularly so in the 5-10cm layer of these pasture soils which is the zone of legume root activity and therefore potential nitrogen leaching. This process has been well documented in its association with soil acidification (e.g. Lockwood *et al.* 2003, Rengel 2003). Soil pH in the 5-10cm layer of these improved pasture soils was found to be as low as pH4.8, a significant threshold below which plant growth and potentially pasture productivity can be greatly impaired (Lockwood *et al.* 2003). This result is all the more surprising on the clay rich, basalt soils that are commonly believed to be well buffered against significant acidification. Our results suggests that soil carbon and nitrogen increased modestly under improved pasture in this region but that this soil change was associated with a significant and potentially damaging reduction in soil pH. Given the recent interest in land-use types and potential carbon storage, we also calculated the carbon density (to 30cm) across the various land-uses examined. When the carbon density was corrected for equivalent mass, using cultivated soils as the standard mass, the woodland sites had a larger quantity of carbon than any other land-use, while the other land-uses remained statistically similar. On an equivalent mass basis, the woodland soils contained, on average, 28 T/ha more carbon than any other land-use sampled. Comparing the various land-use systems sampled, it is therefore clear that in order to maintain the largest quantity of carbon in the landscape of the study area, retaining trees and woodland is the most effective option.

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Measuring particle size distribution: Can the differences among examined soils and methods be proven?

Gergely Jakab[A], **Csaba Centeri**[B], Károly Barta[C], András Bidló[D], Szilárd Szabó[E] and Zsolt Bíró[F]

[A]Research Institute of Geography, Hungarian Academy of Sciences, H-1112-Budapest, XI. Budaörsi ut 45., Hungary, Email jakab@sparc.core.hu
[B]Department of Nature Conservation and Landscape Ecology, Institute of Environmental and Landscape Management, Faculty of Agricultural and Environmental Sciences, Szent István University, 2103-Gödöllő, Páter K. u. 1., Hungary, Email Centeri.Csaba@kti.szie.hu
[C]University of Szeged, Department of Physical Geography and Geoinformatics, H-6720, Szeged, Egyetem u. 2., Hungary, Email barta@earth.geo.u-szeged.hu
[D]University of West Hungary, Faculty of Forestry, H-9400, Sopron, Ady E. u. 5., Hungary, Email abidlo@emk.nyme.hu
[E]Debrecen University, Department of Landscape Protection and Environmental Geography, Egyetem tér 1., 4032 Debrecen, Hungary, E-mail: szszabo@delfin.unideb.hu
[F]Institute for Wildlife Conservation, Faculty of Agricultural and Environmental Sciences, Szent István University, 2103-Gödöllő, Páter K. u. 1., Hungary, Email bzsolt@ns.vvt.gau.hu

Abstract
Knowledge on particle size distribution of soils is the basis for construction activities (green field investments, houses, roads etc.), land use, soil management, soil protection, soil fertilizing etc. It plays an important role in the everyday life of people. Numerous methods exist for measuring particle size distribution. Older ones are used just as well as new technologies. A continually increasing need for precisely measured soil parameters is obvious and there is also a big need for easier methods and for exclusion of as much influencing circumstances as possible. The present research focuses on the comparison of different methods used in Hungarian institutions. Eight soils were analysed in four institutions with three methods. Different analytical methods produced different results for particle size distribution. χ^2 analyses revealed significant differences with different p values. There was a big influence detected by laboratory personnel (the analyses were repeated and one method had less than 5% error, while another had more than 20%). It appears that not only do the well known differences between methods, sample preparation and physical background matter but also there are other factors (e.g. routine vs closely checked analyses) which may influence the results.

Key Words
Particle size, laboratory measurement, comparison of methodologies, comparison of classes.

Introduction
Soil particles serve as a basis for understanding numerous soil processes. Particle-size distribution (PSD) is often used in estimating soil moisture characteristics or hydraulic conductivity (e.g. water-retention curve (Gupta and Larson 1979), saturated conductivity (Mishra *et al.* 1989), unsaturated conductivity (Bittelli *et al.* 1999; Arya and Paris 1981; Campbell and Shiozawa 1992, Alexander *et al.* 1987), and for various other purposes, e.g. for nutrient acquisition (Anderson *et al.* 2006), etc. Determination of PSD by sieving, hydrometer, pipette methods or by laser diffraction (LD) (Bah *et al.* 2009, Hernádi *et al.* 2008) suffers from inherent flaws, mainly due to the difficulty in defining the size of irregularly shaped particles (Eshel *et al.* 2004). Estimating hydraulic properties from particle-size data is preferred when studying soil moisture at catchment or watershed scales. In these cases a detailed characterization of hydraulic properties is usually not possible but particle-size data may be available from regional or national soil databases (Skaggs *et al.* 2001, Nemes *et al.* 1999). Unfortunately, many databases do not contain the full particle-size distribution; only the sand, silt, and clay mass fractions (Skaggs *et al.* 2001, Arya *et al.* 1999). In the present study we wish to analyse different samples and methods to show the possibility of proving similarities or differences.

Methods
Aerometer method: the method is based on measuring the density of soil suspension at different times during sedimentation (MSZ 14043/3: 1979). The aerometer method was used by the University of Szeged.
Pipette method: samples are taken from the settling soil suspension at 5 different times with a pipette. Samples are dried and weighed then the different fractions are calculated based on Stokes' law (MSZ-08-0205: 1978). The pipette method was used by the University of Szeged, Debrecen and West Hungary.
Laser method: the Geographical Research Institute of the Hungarian Academy of Sciences used the laser

method to measure particle sizes with Laser Particle Sizer Analysette 22 MicroTec.
Explanation of codes of sample sites is in Table 1. Hierarchical Cluster Analysis was used to find similar samples, while the χ^2 test was used to find similarities among the methods used.

Results

Results of particle size measurements with different methods applied on eight samples are in Table 1.

Table 1. Results of particle size measurements in different institutes with various methods.

Sample code	Particle size class, Replicate 1/3				Sample code	Particle size class, Replicate 2			
	<0.002	0.002-0.02	0.02-0.05	0.05-2		<0.002	0.002-0.02	0.02-0.05	0.05-2
S_BOR_A_1	5.0	26.3	34.7	34.0	S_BOR_A_2	11.4	15.6	48.0	25.0
S_GAH_A_1	18.2	36.3	18.5	27.0	S_GAH_A_2	18.2	36.3	22.0	23.5
S_GFH_A_1	21.6	30.4	18.0	30.0	S_GFH_A_2	19.5	31.5	14.5	34.5
S_SZG_A_1	15.0	33.8	29.2	22.0	S_SZG_A_2	15.0	32.2	31.8	21.0
S_TUR_A_1	29.0	31.0	21.5	18.5	S_TUR_A_2	29.0	29.0	23.0	19.0
S_KMA_A_1	0.0	1.0	3.0	96.0	S_KMA_A_2	0.0	2.0	5.2	92.8
S_FES_A_1	15.5	18.0	26.5	40.0					
S_GAL_A_1	11.8	32.7	37.7	17.8	S_GAL_A_2	11.0	32.0	26.4	30.6
S_BOR_P_1	4.2	8.4	7.0	80.4	S_BOR_P_2	5.1	8.7	6.2	79.9
S_GAH_P_1	39.6	29.1	1.2	30.1	S_GAH_P_2	37.9	28.1	1.0	33.1
S_GFH_P_1	37.0	32.8	11.2	19.1	S_GFH_P_2	35.9	36.4	12.0	15.7
S_SZG_P_1	10.0	31.5	24.8	33.7	S_SZG_P_2	9.8	30.1	24.7	35.5
S_TUR_P_1	18.4	31.1	17.1	33.3	S_TUR_P_2	18.2	30.2	17.0	34.6
S_KMA_P_1	0.4	2.6	0.2	96.8	S_KMA_P_2	0.4	2.7	0.2	96.7
S_FES_P_1	12.6	22.8	15.9	48.7	S_FES_P_2	10.9	22.4	15.3	51.4
S_GAL_P_1	10.2	26.3	32.2	31.2	S_GAL_P_2	10.1	25.7	33.2	31.1
F_BOR_L_1	3.4	38.2	26.6	31.8	F_BOR_L_1	3.4	38.2	26.6	31.8
F_GAH_L_1	20.1	65.7	8.0	6.2	F_GAH_L_1	20.1	65.7	8.0	6.2
F_GFH_L_1	21.0	64.0	9.2	5.8	F_GFH_L_1	21.0	64.0	9.2	5.8
F_SZG_L_1	9.7	58.4	16.6	15.3	F_SZG_L_1	9.7	58.4	16.6	15.3
F_TUR_L_1	21.1	61.8	10.5	6.7	F_TUR_L_1	21.1	61.8	10.5	6.7
F_KMA_L_1	1.1	4.5	1.7	92.7	F_KMA_L_1	1.1	4.5	1.7	92.7
F_FEF_L_1	7.3	41.6	12.4	38.7	F_FEF_L_1	7.3	41.6	12.4	38.7
F_GAL_L_1	14.7	53.6	19.5	12.2	F_GAL_L_1	14.7	53.6	19.5	12.2
D_BOR_1	1.9	16.2	20.5	61.4	D_BOR_2	5.3	28.7	21.9	44.1
D_GAH_1	27.0	44.8	15.6	12.6	D_GAH_2	31.4	39.6	17.9	11.1
D_GFH_1	27.5	47.2	12.6	12.7	D_GFH_2	25.0	42.9	17.1	15.0
D_SZG_1	8.4	39.7	27.1	24.8	D_SZG_2	7.4	38.0	26.5	28.1
D_TUR_1	32.1	40.4	15.8	11.7	D_2UR_2	26.5	37.2	21.3	15.0
D_KMA_1	0.0	0.7	6.1	93.2	D_KMA_2	0.0	0.2	1.4	98.4
D_FES_1	10.6	32.5	21.5	35.4	D_FES_2	5.3	22.9	20.7	51.1
D_GAL_1	9.0	38.7	34.8	17.5	D_GAL_2	7.8	36.2	32.0	24.0
N_BOR_1	7.0	30.0	53.2	9.8	N_BOR_2	5.0	32.0	51.7	11.3
N_GAH_1	45.0	28.0	24.7	2.3	N_GAH_2	47.0	24.0	26.5	2.6
N_GAH_3	47.0	24.0	26.3	2.7					
N_GFH_1	47.0	26.0	25.0	2.0	N_GFH_2	49.0	22.0	27.1	1.9
N_GFH_3	47.0	24.0	26.8	2.2					
N_SZG_P_1	25.0	28.0	44.6	2.4	N_SZG_P_2	23.0	34.0	40.6	2.4
N_SZG_P_3	25.0	32.0	40.4	2.6					
N_TUR_1	47.0	26.0	24.2	2.8	N_TUR_2	47.0	26.0	24.1	2.9
N_TUR_3	47.0	24.0	26.2	2.7					
N_KMA_1	3.0	0.0	25.1	71.9	N_KMA_2	3.0	0.0	25.7	71.4
N_KMA_3	3.0	0.0	26.8	70.3					
N_FES_1	21.0	16.0	35.6	27.4	N_FES_2	21.0	20.0	36.0	23.0
N_FES_3	21.0	18.0	37.3	23.7					
N_GAL_1	21.0	32.0	43.5	3.6	N_GAL_2	21.0	30.0	45.2	3.8
N_GAL_3	27.0	28.0	41.7	3.3					

S=Univ. of Szeged, F=Hungarian Academy of Sciences, D=Univ. of Debrecen, N=Univ. of West Hungary, BOR=Borzsony, GAH=Gyongyostarjan, lower slope third, GFH=Gyongyostarjan, upper slope third, SZG=Szt.Gyorgyvar, TUR=Tura, KMA=Kiskunmajsa, FES=Fs, GAL=Galgaheviz, A=Aerometer, P=Pipette, L=Laser

Based on the results of particle size measurements (Table 1) two approaches were used to analyse the data. First the groups were formed by Pearson Correlation. Hierarchical cluster analyses show the connection between the different examined soils (Figure 1).

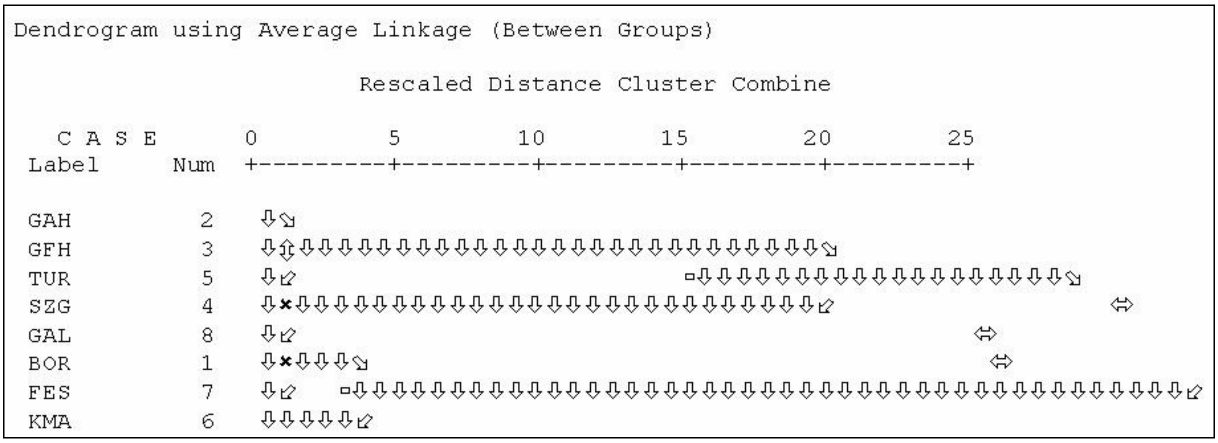

Figure 1. Hierarchical Cluster Analyses of the data of groups formed by Pearson Correlation

The second group was formed by Squared Euclidean Distance method.

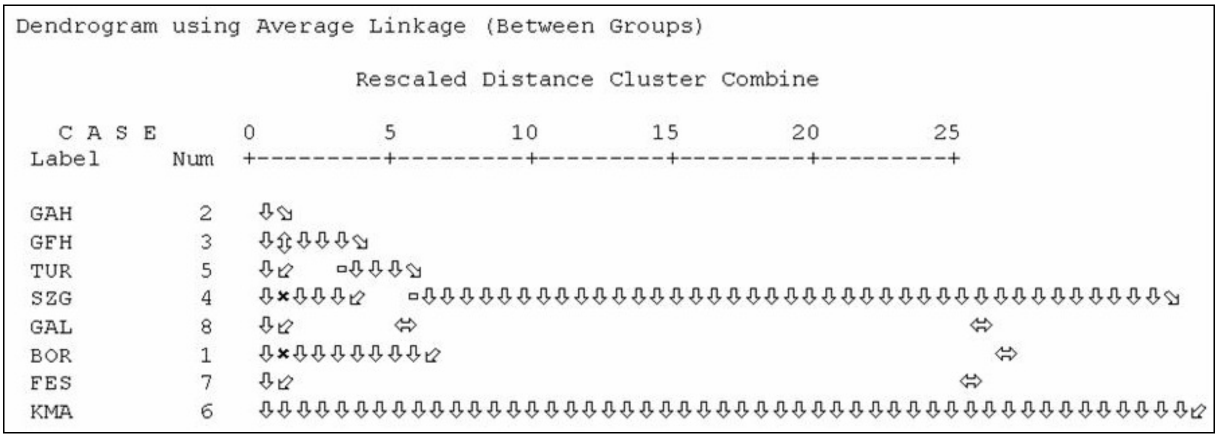

Figure 2. Hierarchical Cluster Analyses of the data of groups formed by Squared Euclidean Distance method.

Both methods of group separation gave the same results, revealing similar groups are as follows:

1. GAH, GFH, TUR;
2. SZG and GAL;
3. BOR and FES (similar but a little further away is KMA);

Values for χ^2 were examined to reveal significant differences among the measurement methods. The measured values were compared to the theoretical values, based on the homogeneity test of the measured values (Table 2).

Table 2. Results of statistical analyses.

Sample sites	df	Critical value	p	χ^2 value
Borzsony (BOR)	6	16.8	<0.01	19.83
Gyongyostarjan (GAH)	6	22.5	<0.001	43.80
Gyongyostarjan (GFH)	6	22.5	<0.001	52.54
SztGyorgyvar (SZG)	6	16.8	<0.01	18.53
Tura (TUR)	6	22.5	<0.001	29.33
Kiskunmajsa (KMA)	6	12.6	<0.05	15.09
Fs (FES)	6	16.8	<0.01	20.97
Galgaheviz (GAL)	6	16.8	<0.01	18.79

According to Table 2, there are significant differences between the measurements. In case of the Borzsony site the clay fraction was measured the most accurately and the pipette method measured higher amounts than the other methods. On the Gyongyostarjan site at the bottom third of the slope, the fine sand fraction was measured the most accurately and the pipette method measured clay more accurately, the aerometer method measured the coarse sand and the laser method the silt fraction more accurately than other methods. On the Gyongyostarjan site over the upper third of the slope the very fine sand fraction was measured most accurately. In case of Szt.Gyorgyvar the clay and coarse sand fractions were measured most accurately. In the other two fractions the laser method gave the best result, with the other two methods giving less than the theoretical values. In case of the Tura site, despite a high sand content the clay fraction was estimated the most accurately. In case of Kiskunmajsa, the coarse sand fraction was measured most correctly because there were only very small proportions of the other size fractions. On the Fs site the coarse sand fraction was measured best. The laser method results differed the most. On the Galgaheviz site the clay fraction was measured best and the laser method differed the most.

Conclusions

Different analytical methods produced different results for particle size distribution. χ^2 analyses revealed significant differences with different p values. These results can be helpful in seeking the sources of errors. In the present case there was a big influence detected by laboratory personnel (the analyses were repeated and one method had less than 5% error, while another had more than 20%). It appears that not only do the well known differences between methods, sample preparation and physical background matter but also there are other factors (e.g. routine vs closely checked analyses) which may influence the results.

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Modeling regional and vertical variation effects when estimating soil nitrogen from loss on ignition

A. Leon[A], M. S. Cresser[B] and R. Leon[C]

[A]National Institute for Agro-Environmental Sciences, 3-1-3 Kannondai, Tsukuba, 305-8604, Japan, Email leon@affrc.go.jp
[B]Environment Department, The University of York, Heslington, York, YO10 5DD, UK, Email msc@york.ac.uk
[C]National Graduate Institute for Policy Studies (GRIPS), 7-22-1 Roppongi, Minato-ku, Tokyo, 106-8677, Japan

Abstract
Knowledge of soil total N stocks is potentially a useful basis for environmental planning and management and in the design of pollution abatement strategies. However, a shortage of data for soil total N deep in the soil profiles makes calculation of the total N pool in soils difficult. We have examined how regional and vertical variations are best taken into account when loss on ignition (LOI) is used to predict missing values of soil total N as measured by the semi-micro Kjeldahl method. Even though statistical tests indicated significant spatial variations, prediction error was little reduced by taking the spatial information into account (i.e. a 4.5% reduction), except for B and C horizon soils, where the reduction was larger by taking account of depth (25.0% and 14.3%). Therefore, one can predict total N (%) across a range of soils by multiplying LOI (%) by 0.020. This approach is useful when one uses published data with much more abundant LOI data for soil profiles than directly determined total N data. However, this can only be used to obtain a quick and approximate estimate of total N.

Key Words
Bayesian information criterion, cross-validation, soil parent material.

Introduction
It is a challenge for sustainable land and water resource management to avoid practices or nitrogen (N) pollution loads that result in adverse changes in the soil total N pool, while meeting the demands of society, such as increase in agricultural output. For this purpose, it becomes vital to understand quantitatively what factors govern total N pool in the soil. However, the calculation of soil total N pool often is made difficult by a shortage of data for total N in available soil survey data (Batjes 1996), especially deeper in soil profiles. To circumvent this problem, regression equations based on the relationships between total N, as measured for example by the semi-micro Kjeldahl method, and LOI may be used. Missing N values may then be imputed when LOI data are available. While the C *vs* LOI relationships have been analysed by many studies (e.g. Ball 1964 among others), total N *vs* LOI relationships seem to have been investigated only by Jackson (1958) and Craft *et al.* (1991). Little attempt has been made to assess regional and vertical variations in soil total N *vs* LOI relationships. Furthermore, none of these studies examined whether taking account of these factors improves total N prediction. Differences in mineral types and relative amount of clay minerals might change the way in which temperature affects LOI values (e.g. Ball 1964). In addition, the soil C:N ratio is likely to change with depth (e.g. Vejre *et al.* 2003). Consequently, the equations that describe total N *vs* LOI relationships might vary among parent materials or depth in a soil profile. However, even if these factors affect the relationships, failure to include them into the regression equation used for prediction might not significantly affect total N out-of-sample prediction.

Therefore, the aims of this paper were (1) to test the hypothesis that the relationships between total N and LOI change with soil layer position (depth) in the soil profile, with soil parent material, and/or with type of soil horizon and (2) to check whether exploiting this spatial information helps to improve out-of-sample predictions of total N. Although LOI might overestimate organic matter components in soil because of carbon dioxide driven from carbonates and water released from soils containing large amounts of clay (e.g. Robinson 1949), we decided to investigate the use of LOI for predictive purposes because LOI data are much more abundant for soil profiles than directly determined total N data.

Materials and methods
Data resources for calibration: We used readily available soil survey data taken from the Country round Aberdeen, Inverurie and Fraserburgh (Glentworth and Muir 1963). The area is in north-east Scotland, to the north and west of Aberdeen, and covers 1617.3 km^2. Soils in this area developed on a diverse range of parent

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materials (Table 1). A total of 160 soil profiles had data recorded for LOI and total N Loss on ignition was measured for horizons from the surface to 1.04 m on average, whereas total N was measured from the surface to 278 mm on average. Twenty three soil profiles were natural (minimally managed) profiles and the others were cultivated soils. The average depths for LFH (n=12), A (n=60), B (n=124) and Ap (n=149) horizon soils were 76, 102, 102, 163 mm, respectively. There was no directly determined total N for the C horizon soils. Total N in the entire calibration (n=345) ranged between 0.02 and 1.98 (mean 0.27, standard deviation: SD 0.32). Loss on ignition ranged between 0.08 and 95.0 (mean 11.5, SD 14.7).

Table 1. Area covered by each of the 12 Associations used in the present study, in km^2 and as a proportion of the total area of Scotland (data from the Macaulay Institute for Soil Research 1984).

Associations	Parent material	Area (km^2)	Area (%)
Boyndie/ Corby	Fluvio-glacil sands and gravels derived from acid rocks	2377	3.08
Collieston	fluviatile deposits derived from Old Red Sandstone sediments together with gravel layers	153	0.20
Countesswells	till derived from granites and granitic rocks	4435	5.75
Foudland	till derived from weakly metamorphosed rocks	2508	3.25
Insch	till derived from basic igneous rocks	518	0.67
Cuminestown/ Ordley	till derived from Old Red Sandstone sediments and argillaceous schists	166	0.22
Peterhead	till derived from sedimentary rocks of Old Red Sandstone sediments	138	0.18
Strichen	till derived from quartz-mica-schist	6151	7.98
Tarves	till derived from acid and basic rocks	1595	2.07
Tipperty	lacustrine sediments derived from Old Red Sandstones	51	0.07

Independent validation data: Data for model validation came from both within and outside the geographical area used for calibration. The data were originally produced by the Soil Survey of Scotland in Aberdeen, and made available from the Macaulay Institute (J. Gauld, pers. comm.). Total N and LOI (n=1007) ranged between 0.01 and 3.52 (mean 0.42, SD 0.57) and between 0.50 and 98.3 (mean 16.7, SD 24.2), respectively. Analytical methods for both validation and calibration data sets: Loss on ignition was measured on 5 to 10 g of finely-ground samples (2-mm sieved). Ground and sieved air-dried samples were weighed and oven-dried at 105 ºC for a minimum of 3 hours and reweighed. Then they were ignited at 800-900 ºC for 30 minutes, which is higher than commonly used for ignition. Therefore, the extent of overestimation might be larger. Soil N was determined by the semi-micro-Kjeldahl method (Glentworth and Muir 1963).

Statistical methods: We considered influences of three types of spatially variable information (i.e. layer position, parent material and soil horizon) on total N - LOI relationships. Four sets of dummy variables were used to represent the spatial information: 1 dummy to stand for information on the upper layer, 11 dummies for parent material, 4 dummies for type of soil horizon, and 23 dummies for soil layer and parent material at the same time (i.e. this set includes a dummy variable for each combination of parent material and soil layer). With these dummies, we considered nine ways of representing spatial information in N - LOI relationships, as shown in Table 2. All of these included a function of LOI (*f*(LOI)). One of these models did not include information on spatial variation (i.e. it included only *f*(LOI)). Four other models represented spatial information by including only a set of intercept dummies, whereas another four included, in addition to one set of intercept dummies, interactions between *f*(LOI) and the dummies. In each model that took spatial information into account, an F-test was carried out to analyse whether the spatial regressors were statistically significant.

Table 2. Description of models.

	Regressors	*k* in Linear
Model 1	*f(LOI)*	2
Model 2	*f(LOI)*, D_U and interactions between *f(LOI)* and D_U	4
Model 3	*f(LOI)* and D_U	3
Model 4	*f(LOI)*, D_P and interactions between D_P and *f(LOI)*	24
Model 5	*f(LOI)* and D_P	13
Model 6	*f(LOI)*, D_{UP} and interactions between D_{UP} and *f(LOI)*	48
Model 7	*f(LOI)* and D_{UP}	25
Model 8	*f(LOI)*, D_S and interactions between D_S and *f(LOI)*	10
Model 9	*f(LOI)* and D_S	6

D_U consists of 1 dummy for the upper layer, D_P of 11 dummies for parent material, D_S of 4 dummies for soil horizon and D_{UP} of 23 dummies for each combination of soil layer and parent material. *k* is the number of regressors including the intercept constant. The equations derived in this study were used subsequently to predict total N values for the validation data set. In order to compare the prediction accuracy, the root mean square error (RMSE) and leave-one-out cross validation analyses (Geisser 1975) were carried out. For the latter analysis, as an additional assessment of the prediction accuracy of each equation, the validation and calibration datasets were pooled. In both standard validation and cross validation analyses, predictions for total N were truncated at 0% or 100% whenever model predictions lay outside the interval (0-100%). We calculated RMSE using sample weights for the validation sample (Deaton 1997) to get an unbiased estimation of the overall average error for Scottish soils. The weight for each observation depended on the Soil Association to which it belonged and was equal to the area in km^2 of each Soil Association in Scotland (Table 1). With regard to the RMSE analysis, as noted before, there were no directly measured total N data for C horizon soils in the calibration data set, which is a common situation in many studies, since data on C horizons is less available. Because of this, when making predictions for C horizon using models 8 and 9 (Table 2), a natural approach would be to predict total N for C horizon in the same way as one would predict it for B horizon soils, since it is the nearest horizon. This was the approach taken in the RMSE analysis. Note that this difficulty did not arise in the cross validation analysis, as in this case the sample did include data from C horizons.

Results and discussion

Bayesian information criterion (BIC, Schwarz 1978) preferred models that took type of soil horizon into account (Table 3). That is, models 9 and 8 are preferred. The estimated coefficients derived in Model 8 are shown in Table 4. This result was also supported when calibration and validation data were merged. Furthermore, it was found that in all models, except for model 5, the spatial regressors were jointly significant at a 1% significance level (Table 3). Moreover, if the calibration and validation data were pooled, the spatial regressors were jointly significant at a 1% level or less in all models (except for model 5). The slope of a simple linear equation derived in this study was 0.020 (Table 4). This slope is similar to that previously determined by Jackson (1958) for terrestrial soils (0.022-0.03) and by Craft et al. (1991) for marsh soils. However, the results of the F-test showed that the equations derived in this study differed significantly from their studies at a 1% level.

Table 3. The Bayesian information criterion (BIC) values† and the results of F-test checking the significance of spatial regressors.

	Linear equation (n=345)								
	Model1	Model 2	Model 3	Model 4	Model 5	Model6	Model 7	Model 8	Model 9
BIC	276	317	296	235	248	228	240	395	350
p-values	-	0.000	0.000	0.003	0.633	0.000	0.000	0.000	0.000
	Linear equation when calibration and validation data were combined (n=1352)								
BIC	140	160	163	132	111	90	108	181	174
p-values	-	0.000	0.000	0.000	0.039	0.000	0.000	0.000	0.000

†a model with the largest BIC is most preferable.

Table 4. The equation preferred by Bayesian information criterion (BIC) and the simple linear equation.

Equation preferred by BIC (Model 8) †

Total N%=0.049+0.016×LOI +(-0.082+0.009×LOI)$D_{A\ horizon}$+ (-0.002+0.008×LOI)$D_{Ap\ horizon}$ + (-0.040+0.001×LOI) $D_{B\ horizon}$

s.e. (0.053) (0.001) (0.054) (0.002) (0.063) (0.004) (0.054) (0.002)

The simple linear equation (Model 1)

Total N%=0.038+0.020×LOI

s.e. (0.011) (0.001)

†Note that the set of potential explanatory variables does not include a dummy for LFH horizon in Model 8. This omission is necessary to avoid a problem of perfect multi-collinearity.

Despite these statistical results, however, RMSE in the standard validation analysis and cross-validation exercises was not smaller in models that accounted for spatial information (Table 5). Cross-validation excises showed RMSE was reduced by only 4.5% by taking account of the spatial information (this was also found when *f*(LOI) was quadratic). However, RMSE in cross-validation exercises showed that prediction errors in B and C horizon soils were reduced by 25.0% and 14.3%, respectively, when information on type of soil horizon was used (model 8). This result suggests the importance of taking account of type of soil horizon, which can be attributed to change in soil C:N ratio with depth (e.g. Vejre *et al.* 2003). Furthermore, LOI is overestimated more when LOI values are smaller than when LOI values are larger (Howard 1965). One of the sources of variation not accounted for in our approach is amount of inorganic nitrogen. Organic matter as measured by LOI was used to predict total N analysed by the semi-micro Kjeldahl method, since most of nitrogen is organically bound. However, inorganic N cannot be predicted with LOI. The amounts of inorganic nitrogen will differ with several factors, such as pH (Ste-Marie and Pare 1999), or temperature, moisture (Sierra 1997; Agehara and Warncke 2005).

Table 5. The root mean square error and cross validation values for each model†.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model6	Model 7	Model 8	Model 9
					RMSE (linear equation) (n=1007)				
All	0.26	0.28	0.26	0.31	0.27	0.27	0.26	0.30	0.29
					Cross validation (linear equation)				
All	0.22	0.21	0.21	0.21	0.22	0.21	0.21	0.21	0.21

†Note that with regard to the RMSE analysis, when making predictions for C horizon using models 8 and 9, total N was predicted in the same way as one would predict it for B horizon soils, since there was no directly determined total N for this horizon. On the other hand this difficulty did not arise in the cross validation analysis, as in this case the sample did include data from C horizons

Conclusions

Failure to include regional and vertical variations in total N measured by the semi-micro Kjeldahl method *vs* LOI relationships into the regression equation did not significantly affect total N prediction. However, for B and C horizon soils it appears probable that a significant influence of soil horizon on LOI *vs* total N exists. Accordingly, one can predict total N across a range of soils by multiplying LOI by 0.020 for surface horizons. This approach is useful when one uses published data with much more abundant LOI data for soil profiles than directly determined total N data. However, this can only be used to get a quick and approximate estimate of total N.

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Participatory and demand-driven land evaluation: an on-going experience in Lontras, Santa Catarina, Brazil

Ivan Luiz Zilli Bacic[A], Roberta Pereira Martins[B], Juniele Rodrigues Pivetta[C] and Denilson Dortzbach[D]

[A]Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina (CIRAM), Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), Florianópolis, SC, Brasil, Email bacic@epagri.sc.gov.br; ivan.zilli@gmail.com.
[B] Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) at Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina (CIRAM), Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), Florianópolis, SC, Brasil, Email robervalda@hotmail.com.
[C]Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) at Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina (CIRAM), Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), Florianópolis, SC, Brasil, Email batateiraju@hotmail.com.
[D]Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina (CIRAM), Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI), Florianópolis, SC, Brasil, Email denilson@epagri.sc.gov.br, agrofloripa@yahoo.com.br

Abstract
Results of soil and land evaluation survey and mapping, which were expected to be essential to land use and management planning, most of the time are not adequately used by their potential users and rarely reach the decision makers. In this context, the objective was to test a participatory land evaluation methodology to make the information more useful and consequently more used by the decision makers. The work is being developed in three municipalities in different regions of Santa Catarina State, Brazil: Lontras (Upper Itajaí River Valley), Luzerna (Mid-West) and Barra Bonita (West). However, the experience described here refers only to Lontras. The study started with meetings, interviews and questionnaires with farmers, local professionals and leaders, and the following main demands were raised: (1) irregular and low production of cucumber; (2) need for area expansion and management improvement of the pastures; and (3) information about the actual environment regulation and its implications to the farmers. Lately other meetings were prepared to present and assess the relevance and quality of the demanded information, and to re-evaluate the priorities. The expected following steps were presented, but changes may occur, considering that rural activities are dynamic and other priorities may appear.

Key Words
Land inventory, participatory research, land use and management planning.

Introduction
Land evaluation is the process of predicting land performance over time according to specific land use types (Van Diepen *et al.* 1991; Rossiter 1996). These predictions are then used to guide strategic land use and management decisions. So, one would expect that land use planners and other decision-makers who influence rural land use would be eager to use the results of land evaluation. However, the results from land inventories and soil and land evaluation surveys and mapping, most of the time are not use by the decision maker, be it farmers, planners or politicians themselves (Rossiter 1996; Bouma 1999; Bacic 2003; Bacic *et al.* 2003). Land users and planners have systematically ignored this works, reflecting the low relevance of many land evaluation and soil survey reports, as well as the poor communication with the potential users of the information. Bacic (2003) suggests that the process should begin with a careful analysis of the environment where the stakeholders live, and consequently, where decisions are made, following a participatory and demand-driven methodology. Therefore, it is expected that the decision makers will be given the information they consider more relevant and with more appropriate language. The information will probably be more realistic and consequently more useful not only to the final decision makers (farmers), but also to the rural land use planning agencies, which strongly influence the decisions.

In this context, the use of participatory research methodologies and tools, come out as an important alternative to reach better results to make available information that fulfill the rural families needs. According to Brandão (1984), participatory research refers to the focus on social investigation, searching for the complete community participation on the analysis of their own problems, to promote social participation to benefit all the participants with possible collective solutions. Thus, the general objective of the experience was to test a participatory and demand-driven land evaluation methodology as proposed by Bacic (2003), in order to optimize the use of the existing information, to drive the search for new information and to generate realistic land use and management options from which the decision-makers could choose, considering social, economic and environmental aspects.

Methods

The experience is part of the project "Demand-driven land evaluation", that is being developed in three municipalities in Santa Catarina State, Brazil, by the "Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina – EPAGRI", with financial support from the "Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq", the "Ministério do Desenvolvimento Agrário/Secretaria de Agricultura Familiar – MDA/SAF"and the "Ministério do Desenvolvimento Social e Combate a Fome/Secretaria Nacional de Segurança Alimentar e Nutricional – MDS/SESAN". The project started on December/2007 and will last for 30 months. Three municipalities were selected according to the following main criteria: (1) location on three different regions in Santa Catarina State; and (2) acceptance and support of local teams (extensionists), local government and primarily the communities. Following these criteria and after several meetings, the following municipalities were selected: Lontras (Upper Itajaí River Valley), Luzerna (Mid-West) and Barra Bonita (West).

This work shows the results obtained up to now in Lontras municipality. The study area, "Concórdia Microcatchment", was selected in a meeting with local leaders. The first step was to raise the demands for interpreted information (e.g. land evaluation, climatic risks, production systems, economic information, amongst others), according to the local decision makers (farmers, extensionists and local leaders) needs. The demands were raised in meetings, after a presentation, questionnaire application and interviews. At this time, in order to understand better the local conditions, the farmers also answered general questions about farm size, number of people working in the farm, main rural activities, if they wanted to improve or even abandon these activities, as well as if they had the intension to start a new activity and which information would be necessary to make this decision. The demanded information was then organized and ordered following the priorities, according to the urgency and frequency.

Next, other meetings were organized, to present the demanded information, as well as to assess the relevance and quality of the demanded information, to evaluate the tools and methods used, and to re-evaluate the priorities according to the participants' opinions. The methodology is based on several negotiation rounds, and up to the end of the project it is expected to find in a collective way, different land use and management techniques, new options to increase incomes without environmental damages, improving the rural families social inclusion and their life quality.

Results

The present work shows the results obtained up to now in Lontras municipality. The study area, "Concórdia Microcatchment", is one of the seven monitored microcatchments (water quality, socio-economical aspects, etc.), through the "Microcatcment 2 Project" with support from the World Bank. Besides the factors already mentioned above, other important aspect used to choose the study area, was the existence of information about the environment, as soil, climate, land use, socio-economical information, amongst others. This previous knowledge is important for the understanding of the local conditions where farmers make their decisions, how the environment affects their decisions related to land use and management and what is the implication to the existing land evaluation methods.

The first meeting had the participation of 14 families. According to their information, 56 people live in these farms, but only 39 are working there. All the farms are classified as "small family farms", as all of them are less than 20 ha size and most of the labor is from family members. Currently, the main use is with maize/beans (13 out of 14 farms), followed by milk production (7 farms), tobacco and potatoes (5 farms) and cucumber (4 farms). Six out of 14 families declared to be satisfied with their current activities, 7 stated to be slightly satisfied and 1 family mentioned they are unhappy. Nine families declared the intention to improve their current activity or even change for new activities. Five families stated they are not willing to make any changes. The main results of the experience up to now are shown in Table 1. The table shows the demanded information, some already carried out actions, and suggestions for possible actions to be developed in the following project stages. Due to the particular characteristics of the horticulture in Lontras, and the urgency for the problems solution, this demand was the first to be addressed. The first measure was to organize a meeting between the cucumber farmers and the horticulture researcher of the Epagri's Itajaí Experimental

Station. At the meeting the group discussed the current primary difficulties, methodologies to produce cucumber, crop management, fertilization and plant health. Then, because of the recent changes in the cucumber production system, a course was prepared to the extensionists not only from Lontras, but also to the whole Ibirama, Rio do Sul and Ituporanga regions.

Table 1. Raised demands and actions to deal with them.

	Raised Demands	Performed Actions	Suggested Actions
Horticulture (Cucumber)	• Plants health; • High prices of inputs (agrochemicals, fertilizer); • Irregular production; • Low yield.	• Meeting between farmers and horticulture researcher; • Horticulture course to extensionists in the region; • Soil sampling for chemical analysis; • Farmers visit to the Experimental Station.	• Wait for the soil analysis results and organize a meeting with farmers, local extensionists, project group, agro-industry technicians and researchers to discuss possible solutions to the raised problems; • To implement an experimental unity to compare the results of the production system currently used by the farmers with the system recommended by research.
Milk Production	• Added value in milk activity; • Area expansion for pasture; • Increase production and yield.	• Presentation made by milk production and pasture management regional specialist; • Soil sampling for chemical analysis.	• To contact researchers to get more information mainly related to appropriate pasture management; • To take information and encourage local technicians to organize courses to the farmers about on-farm milk industry; • Organize a farmers' visit to Experimental Station and to other farmers that already have improved their pasture and are following research recommendations.
Environmental regulation	• Lack of knowledge about current environmental regulation; • Difficulties to adequate the farms to the environmental regulation.		• Presentation made by environmental regulation regional specialist. • To use GIS tools to spacialize and quantify existing environmental conflicts in the area; • To search for alternatives to adequate the farms to the environmental regulation in order to minimize existing conflicts.
Tobacco	• Health problems.	• Presentation of written material about production system and the crop management.	• To use the soil mapping and other existing information to recommend management practices more specific and appropriated to the region.
Maize and beans	• Improve maize and beans yield.	• Soil sampling for chemical analysis.	• To make efforts to aware farmers about the importance of the soil analysis and to follow the research and extension recommendations.
Potato	• Health problems.	• Local team (extensionists) is working the problem.	• To take more information to the local team to help them to find solutions.

The second priority, established due to the frequency of farmers demanding on this subject, refers to milk production. It was organized a presentation to the farmers made by a regional specialist about milk cattle and pasture management. Soil samples were sent to laboratory to perform chemical analysis in order to check fertilization needs. The extensionists and farmers are organizing visits to the Experimental Station and to other farmers that have better yields and incomes, as they already have improved their pasture and are following research recommendations. It is expected that after these visits, experimental unities will be implemented in the study area, to compare with the system currently in use. The third demand refers to the environmental regulation. The meetings participants and respondents to the questionnaires mentioned their worries about the increasing pressure to preserve the environment and follow the regulations and their lack of knowledge on this subject. Presentations will be performed by specialists from the "Santa Catarina State Environmental Foundation (Fatma)". The main points to be presented are those relevant to the farmers in the region, as for instance the legal compulsory reserve, permanent preservation areas, and the flexibility in the regulations considering the particularities and difficulties of the small farmers. Then, pilot studies will be carried out using GIS tools and techniques to spacialize and quantify environmental conflicts in at least 5 farms, in order to search cooperatively with the local community, alternatives to reduce the conflicts with the minimum of economical losses to the rural families. Another demand, common to several activities was related to soil fertility and fertilizer recommendations. Forty composite soil samples were collected with auger up to 20cm deep, in 26 farms. At this stage, the farmers were asked to answer a questionnaire about the manage ment practices performed in their farms (e.g. fertilizer and lime application), as a complementary information to help the soil analysis interpretation and fertilizer recommendations. The expected following steps are also presented in Table 1, but changes may occur, considering that rural activities are dynamic and other priorities may appear. Finally, an important indirect result of the methodology was the approach between extension and research in the region. It became very clear that the researchers have knowledge and information which were not reaching the extensionists and farmers, and in the other hand extensionists and farmers needed that information and did not know where to find it.

Conclusion

Even before the end of the project, it was already possible to observe several advances in comparison with traditional methodologies currently in use. The participants in the project evaluated positively all the stages performed up till now. Most of the raised demands were for existing information that were not reaching the decision makers, or were reaching them in an inappropriate manner or inadequate language. Even the previously-ignored information they received about three years ago is considered important now, but with a different approach and language. An example is the physical land evaluation and soil information, which were not used when presented in traditional way (maps and reports with specific technical language). This information will be used now as an important support to identify expansion areas to milk production, to recommend the most appropriate pasture according to the different physiographic units, and to the pilot studies to adequate the farms to the environmental regulations. It is expected that with the sequence of this participatory approach for land evaluation, the decision makers will be presented with more relevant information, that really help them to make better decisions. And in case they demand for non-existing information, they can even influence a new direction to future research projects and extension works. The methodology, which was considered promising by Bacic (2003), showed in this experience several sound results, confirming its great potential.

Acknowledgements

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Phosphorus supplying potential of European soils

Helinä Hartikainen and Asko Simojoki

Department of Food and Environmental Sciences, University of Helsinki, Finland, Email helina.hartikainen@helsinki.fi

Abstract

The P supplying power of 26 European benchmark soils was investigated by means of desorption/sorption isotherms (Q/I plots) and by desorption graphs determined at increasing water-to-soil ratios (x). The desorption followed the equation y = c x^a where the parameters *c* and *a* stand for the P concentration in the soil solution at 100% moisture level and the P supplying power of soil, respectively. The parameter *c* correlated closely with the Al-bound P (r = 0.88***) and the P saturation of Al oxides (r = 0.92***) and with labile P (Q_0) (r = 0.83***) and the equilibrium P concentration (EPC_0) (r = 0.92***) derived from Q/I plot. In contrast, the parameter *a* did not correlate very closely with the P quantity parameters, the correlation coefficient with Al-bound P and the P saturation of Al oxide being -0.59** and -0.57**, respectively. Similarly, its correlation with the P buffering power of the sorption isotherm (EBC_0) remained rather weak (r = 0.47*), suggesting that the slope of the Q/I graph will change at concentrations below the EPC_0 value. This means that the labile P (Q_0) derived from the Q/I plot at a fixed solution to soil ratio may underestimate the labile P reserves of the solid phase.

Key Words

P buffering, P supplying power, P desorption, Q/I plots, P exchange

Introduction

In soil, the release of labile phosphorus (P) from soil particles resupplies P taken up by plants from the soil solution. The same mechanism maintains a dynamic equilibrium between solid and solution phase, and explains the eutrophication risk caused by the runoff water in contact with surface soil and carrying erosion material to watercourses. The dissolved P in runoff water correlates positively with readily extractable P in surface soil (e.g. Sharpley *et al.* 1977; Culley *et al.* 1983; Pote *et al.* 1996). However, the common P tests based on single extractions do not describe adequately the capacity of soil material to buffer the changes in the solution phase. The P buffering power is a function of the quantity of sorbed P (Q) and its intensity (I) controlled by the coverage of sorption components by phosphate and ligands competing with it.

The quantity/intensity model (Q/I) model by White and Beckett (1964) can be applied to determine the P release from soil or sediment to the ambient solution (e.g. Fox and Kamprath 1970; Hartikainen 1991, Koski-Vähälä and Hartikainen 2001). It allows the prediction of both P sorption to and desorption from the soil, and the slope of the desorption-sorption curve at different points characterizes the P-buffering properties of the soil. Its limitation is, however, that it describes the situation at a given solution-to-soil ratio and easily underestimates the labile P reserves (Yli-Halla *et al.* 2002). In this study, we investigated the P release potential of 26 contrasting European agricultural soils in an extraction test using increasing water-to-soil ratios. The P supplying parameters derived from the desorption graphs were compared with the soil P characteristics and the P exchange parameters obtained from desorption/sorption graphs (Q/I plots).

Material and methods

Soil samples

Twenty-six topsoil samples of "benchmark" soils were collected from across Europe (Austria (AU), Finland (FI), Hungary (HU), Italy (IT), United Kingdom (UK)) as part of the EU DESPRAL project. The soils differed markedly in their weathering degree and other chemical properties, fertilization history, as well as in their lithological origin, a total of five being calcareous (details given in Withers *et al.* 2007).

Methods

Soil samples were analyzed for pH($CaCl_2$), for the easily soluble (NH_4Cl-extractable), Al-bound (NH_4F-extractable) , Fe-bound (NaOH-extractable) and Ca-bound (H_2SO_4-extractable) P pools (Chang and Jackson fractionation method slightly modified by Hartikainen 1979) and for the oxalate soluble Al and Fe oxides (Al_{ox}, Fe_{ox}) (Loeppert and Inskeep 1996). The degree of P saturation (DPS) on the oxide surfaces was calculated as molar ratios of NH_4F-P/Al_{ox} (DPS_{Alox}) and NaOH-P/Fe_{ox} (DPS_{Feox}) according to Hartikainen (1979), and also as a molar ratio P_{oxal}/Al_{ox}+Fe_{ox} (DPS_{Poxal}) of the oxalate soluble P and oxides according to Lookman *et al*. (1995). Total P was determined as described in Withers *et al*. (2007).

Determination of P buffering power
The dynamic equilibrium between the P sorption and solution phase P was depicted by Q/I plots determined at solution to soil ratio of 50:1 using KH_2PO_4 solutions containing P 0-100 mg/l. The P exchange parameters were calculated using a modified Langmuir equation as in Hartikainen and Simojoki (1997):

$$\Delta Q = \frac{Q_{\max} I}{1/K + I} - Q_0$$

where ΔQ is the P amount sorbed or desorbed, Q_{max} is the maximum P sorption, Q_0 is the amount of P that has to be desorbed to decrease the P equilibrium concentration to 0 mg/l (by extrapolation), I is the concentration of P in the equilibrium solution and K is a sorption/desorption equilibrium constant related to the binding strength. The intercept of the Q/I curve on the I axis stands for the equilibrium P concentration EPC_0, where $\Delta Q = 0$. The slope of the curve at EPC_0 was termed the equilibrium buffering capacity (EBC_0). Desorption curves were determined by extracting the soils with water (P_w) at solution-to-soil ratios varying from 2:1 to 1000:1.

Results and discussion
The variation in the different P fractions was very large. Ca-bound P dominated in 16 out of 26 soils (range 58-738 mg/kg) and Fe-P (range 0-734 mg/kg) dominated over Al-P (range10-227 mg/kg) in 19 soils. As for the DPS values, DPS_{Feox} (range 0-50%) was larger than DPS_{Alox} (range 0.4-17%) in a total of 20 soils, but no correlation between the oxide bound P pools and their respective sorption components (Al_{ox}, Fe_{ox}) was found. In the 5 calcareous soils low in oxide bound P, DPS_{Poxal} (range 5.5-36%) markedly exceeded the DPS based on P fractionation. These high DPS_{Poxal} values were probably artefacts caused by the dissolution of Ca-bound P as demonstrated previously (Uusitalo and Tuhkanen 2000; Peltovuori *et al.* 2002).

The P exchange parameters derived from the Q/I plots varied widely, as expected (Table 1). In EPC_0 referring to the 'zero point' of P exchange at which no net desorption from or sorption to soil occurs (Taylor and Kunishi 1971), the range of values was largest as the values varied by more than two orders of magnitude. In contrast, in EBC_0 that stands for the buffering capacity at EPC_0, and in the instantly labile P ($-Q_0$), the variation was less than two orders of magnitude. The smallest relative variation was found in Q_{max}.

The P concentration in the water extracts was expressed as a function of the extraction ratio by the equation:

$$y = c\, x^{a} \qquad (2)$$

where y stands for the P concentration in the extract, x for the solution to soil ratio, *c* for the P concentration in soil solution at moisture level of 100% and *a* for the P buffering power. An example in Figure 1 shows the response of soil solution P to the increasing extraction ratio: in Gleadthorpe soil, the P concentration first sharply decreased when the ratio increased, but then levelled off gradually. The variation in the parameter *c* was larger than that in the parameter *a* (Table 1). The parameters *c* and *a* of desorption graphs correlated negatively with each other (r = -0.68***, n= 26), which means that the P supplying power decreased with an increase in P intensity in the soil solution.

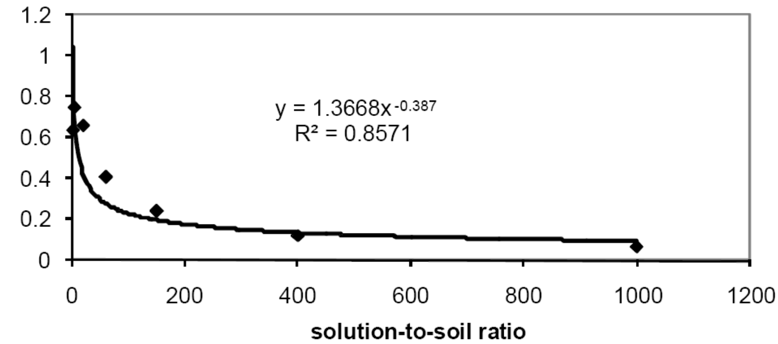

Figure 1. Desorption graph describing the P concentration (y) as a function of water-to-soil extraction ratio (x) in Gleadthorpe soil (Great Britain).

Table 1. The ranges in the parameters derived from the Q/I plots and the desorption graphs in European "benchmark" soils.

Q/I plot parameters	Range	Desorption graph parameters	Range
- Q_0 (mg/kg)	2 – 75	*c* (mg/l)	0.14 – 5.89
EPC_0 (mg/l)	0.00 – 10.3	*a*	-0.026 – -0.610
EBC_0 (l/kg)	5 – 343		
Q_{max} (mg/kg)	43 – 515		

The estimate for soil solution P at 100% moisture level (*c)* seemed to be most closely related to the Al-bound P (NH_4F-P) and the P saturation degree of Al oxide surfaces, whereas the correlation with the Fe-bound reserves remained low (Table 2). The correlations between *c* and the Q/I plot parameters revealed that the higher was the P concentration in the soil solution, the higher were also EPC_0 and Q_0. These two parameters EPC_0 and Q_0 explained 85% and 69% of the variation in the parameter *c*, respectively.

The parameter *a* describing the buffered nature of soil P supplying power did not correlate very closely with the P quantity parameters (Table 2), even though it seemed to increase as the NH_4F-bound P and the P saturation of Al oxides decreased. Interestingly, the correlation between EBC_0 and *a* remained rather weak, even if both parameters describe the buffering of soil solution P. This is probably due to the fact that at concentrations below EPC_0, the actual buffering power will become larger than that estimated on the basis of the EBC_0 values obtained at a fixed solution-to-soil ratio at EPC_0. We also note that the parameter *a* values vary relatively more than the EBC_0 values (Table 1). These results lead to the conclusion that in the conventional Q/I plots determined at a fixed solution-to-soil ratio, the estimate Q_0 will underestimate the labile P, especially at such large solution-to-soil ratios typical of surface runoff waters containing soil particles eroded from topsoil.

Table 2. Correlation coefficients for the relationship between the desorption parameters *c* (the P concentration in the soil solution) and *a* (the P supplying power) with the parameters describing soil P reserves and P exchange (parameters derived from Q/I plots).

	P parameter	Parameter *c*	Parameter *a*
P reserves	NH_4F-P	0.88***	-0.59**
	NaOH-P	0.22	-0.25
	Total P	0.48**	-0.58**
	DPS_{Alox}	0.92***	-0.57**
	DPS_{Feox}	0.19	-0.21
	$DPS_{sesq.ox}$	0.52**	-0.41*
Q/I plot	Q_0	0.83***	-0.50**
	EPC_0	0.92***	-0.46*
	EBC_0	0.57**	0.47*
	Q_{max}	0.27	-0.38*

n = 26; Significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Conclusions

The 26 “benchmark” European agricultural soils covered a wide range in P sorption and desorption properties. The soil solution P estimated from the desorption graph at 100% moisture level increased with increase in the equilibrium P concentration of the Q/I curve and with the P bound to Al oxides. However, it is noteworthy that the ability of soil to maintain high solution P concentration also at higher solution-to-soil ratios decreased more rapidly as Al-bound and soil solution P increased. This P supplying power tended to increase with increase in the equilibrium buffering capacity derived from the Q/I curve. Our results show that European agricultural soils vary widely in their capacity to supply P to surface runoff waters. They also indicate that the traditional determination of P reserves and Q/I curves with a fixed solution-to-soil ratio is likely of limited use for predicting the P loading by eroded soil particles transported to watercourses.

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Shadow analysis field measurements related to soil surface roughness

R. Garcia Moreno[A], A.M. Tarquis[B], M.C. Diaz Álvarez[B], A. Paz González[A], E. Vidal Vázquez[A] and A. Saa Requejo[B]

[A]Facultad de Ciencias. Universidad de La Coruña- UDC, Email Spain (rgarciam@udc.es)
[B]CEIGRAM (Centre for Studies and Research on Agricultural and Environmental Risk Management), Universidad Politécnica de Madrid, SPAIN

Abstract
The present study aimed to fill the need for a reliable, low-cost and convenient method to measure soil surface roughness. Based on the interpretation of micro-topographic shadows, this procedure is primarily designed for use in the field. The principle underlying shadow analysis is the direct relationship between SSR and the shadows cast by soil structures under fixed sunlight conditions. The results obtained with this method were compared to the statistical indexes used to express field readings recorded by pin meter and chain set methods. The tests were conducted on 4-m^2 sandy clay loam plots divided into 1-m^2 subplots tilled with three different implements: chisel, tiller and roller. The highly significant correlation between the statistical indexes and shadow analysis results proved that both variability (CV) and dispersion (SD) are accommodated by the new method. The method also showed a good proportionality with the chain roughness (CR). The SSR obtained for the different methods is mainly related to the presence of aggregates. The shadow analysis simplifies the interpretation of soil surface roughness and shortens the time involved in field operations by a factor ranging from 4 to 20.

Key Words
Shadow analysis, soil surface roughness, chain method, pin meter, erosion

Introduction
Soil surface roughness describes the micro variation in the surface elevation across a field resulting mainly from tillage practices and soil texture and is a major factor influencing wind and water erosion (Vidal *et al.* 2005).Soil surface roughness can predict wind erosion, by defining the potential for soil particle retention, emission and saltation (Hagen 1988; Potter *et al.* 1990). The soils of semi arid regions such as Central Spain suffer mainly from wind erosion where the loss of both organic matter and nutrient-rich topsoil affects soil productivity and air and water quality (Cihacek *et al.* 1993; Larney *et al.* 1999; Saxton 1995). The quantification of soil surface roughness requires field techniques capable of measuring accurately the soil micro relief to capture and analyse data. Therefore, based on previous work (Garcia Moreno 2006; Garcia Moreno *et al.* 2008a, 2008b) the main objective of the project was to study shadow analysis comparing the data to the one obtained from the pin meter technique and the chain set method in a darker soil than in previous field experiments. In this new analysis, shadow analysis method proved again to meet field testing requirements, being simpler, more convenient and quicker than the techniques presently in use. Moreover, when this procedure was calibrated under different roughness conditions the data collected were found to be more readily analyzed and interpreted than the data gathered with existing techniques.

Methods
After laboratory and field validation of the shadows analysis method (García Moreno *et al.* 2008a; 2008b) a test was conducted on 4-m^2 sandy clay loam plots divided into 1-m^2 subplots tilled with three different implements: chisel, tiller and roller. Also the method was used to measure the roughness of a control connsiting of the same soil without tillage. The SSR obtained using shadows analysis was compared to the data obtained from pin meter and chain roller set. The control was measured only with the chain method. The soil had darker color than in previous studies (García Moreno *et al.* 2008a) to obtain different SSR scenarios during the spring of 2009. The experimental field was located on the campus of the Agricultural Engineering Faculty (E.T.S.I.A.) of the Polytechnic University of Madrid (U.P.M.). The resulting SSR after passage of the tillage implements is illustrated in Figure 1. For the capture of the images, a digital camera DC 4800 was used in all the methods. A frame of 1 m^2 was used to take the images assuring that the same area was chosen for every subplot reading.

Shadows analysis images were taken before other measurements to avoid any kind of disturbance produced by other methods of capturing the values (Figure 1). All the images to analyze shadows were taken with a solar angle of 45º to avoid any interference by differences on the shadows. The shadows projected by soil surface roughness were analyzed on byte map histograms using Corel Draw Photo Paint (© 1992–1996 Corel Corporation) software. The points representing shadows on the histogram were identified and converted into a black surface against a white background. The shadow index was then computed as the percentage of black pixels over the total number of pixels.

The pin meter method (Figure 2) was selected as a reference to the field shadow analysis measurements in light of the reliability of this technique (García Moreno *et al.* 2008b). The prototype consisted in a row of 35-cm high pins, placed in a frame in which they could slide up or down to conform to surface irregularities. The pin heads were marked with a blue band to better visualize their respective positions when in contact with the soil. The device was designed to be moved horizontally without disturbing pin patterns. With rows containing 50 pins spaced at 2-cm intervals, each x-axis reading covered one full metre of ground. The images displayed by the pin meter at the different positions, parallel to direction of tillage, were recorded with the camera installed in a Silk tripod adjusted at the middle of the vertical and horizontal distance of the device, in order to avoid the distortion of the images. A program in visual basic was developed to translate the different pin positions of the different images into soil micro relief data.

Figure 1. Shadow analysis, sandy clay loam soil tilled with chisel, tiller and roller, and control, left to right.

Figure 2. Experimental pin-meter.

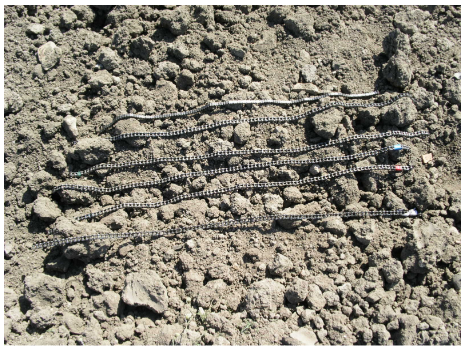

Figure 3.Chain set. Field measurements. Soil tilled with chisel.

In order to express the results obtained from pin meter as SSR, as global soil surface roughness over an area of 1.0 m^2, the present study used the standard deviation (SD) measured between all the data points. The SD accounts for the random and oriented soil roughness. A second index, the coefficient of variation (CV), was used in addition to standard deviation. While the SD results were expressed in cm, CV was expressed as a percentage.

The chain method used a chain set constructed from six ANSI standard roller chains, Figure 3. All the chains were 1 m long. The chains had different links: 0.476 cm, 0.953 cm, 1.91 cm, 3.81 cm 7.62 cm and 15.24 cm. The last four chains were formed after a 0.953 cm linked chain was welded every 2, 4, 8 and 16 links (Figure 3). Then, the soil surface roughness was represented calculating Chain Roughness, CR, and plotted as a log function of the link length (Merrill *et al.* 2001; Saleh 1993). In order to compare the soil surface roughness obtained from the chain set to the shadows analysis, the measurements were taken perpendicular and parallel to tillage; in the first case it represents a combination of oriented and random roughness, while in the second case the data represents the random roughness alone, mainly the aggregates.

Results

Figure 4 shows the results from the pin meter method, SD and CV, and the percentage of shadows. Both methods expressed similar results for the SSR resulting from each tilling tool. The highest roughness is expected with chisel, followed by tiller, roller and control. Even if the correlation between percentage of shadows and CV and SD seems to be high in both cases, the percentage of shadows proved to be closely correlated to CV and SD (99%). Consequently, roughness is influenced by variability and dispersion and the surface roughness observed in the field after tilling is the result of both a large number of low-relief structures associated with the disturbance generated by the tilling tool and a few larger scale structures such as clods or aggregates, as it can be corroborated with the images (Figure 1).The results of the soil surface roughness measured with the chain set, Chain Roughness CR, for the different tilling tools are expressed as function of the chain link in Figure 5. Since the parallel and perpendicular measurements were similar, only the first data were reported.

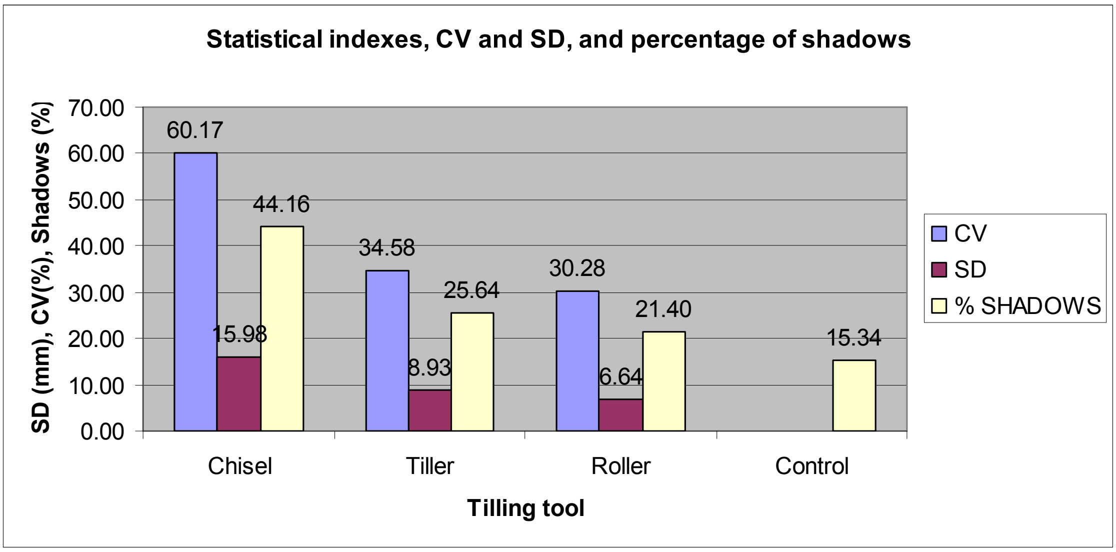

Figure 4. Shadow analysis and pin meter results, percentage of shadows and CV and SD as surface roughness measurements in relation to method of tillage.

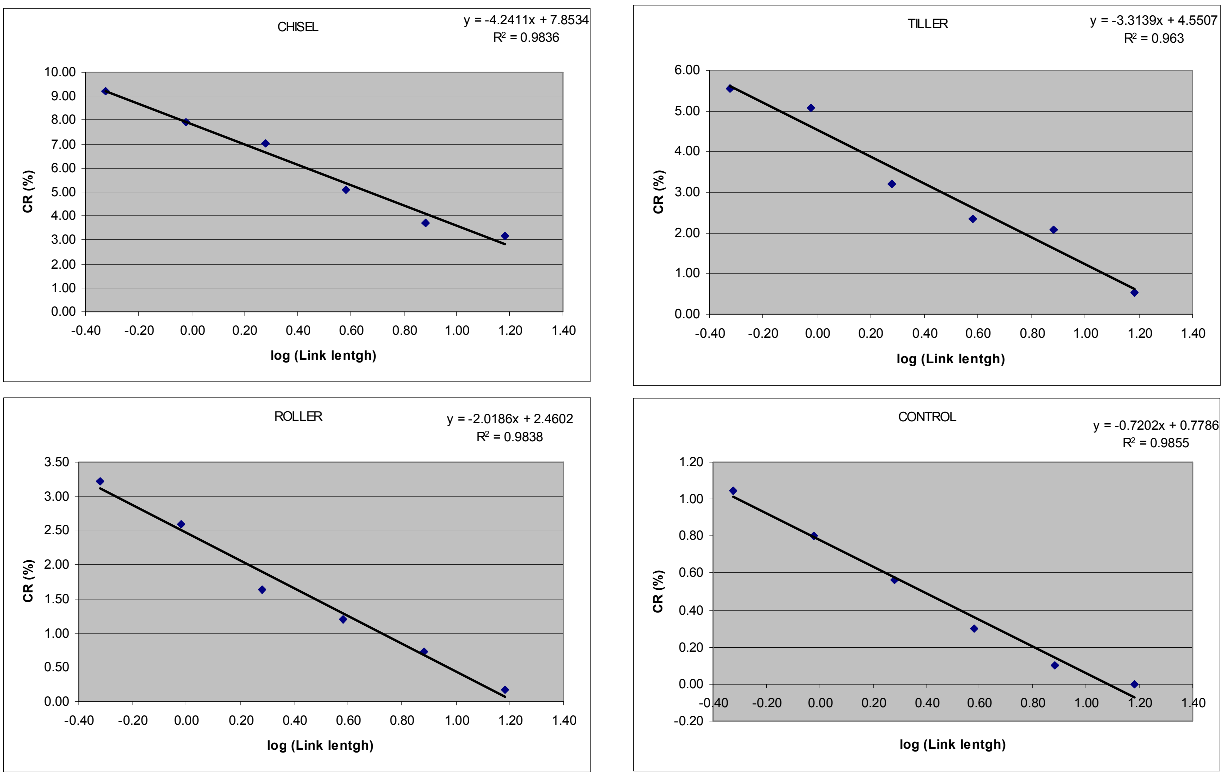

Figure 5. Chain roughness after tilling with different tools and a control.

These results demonstrated that there were no obvious tillage ridges at the site and the predominant soil surface roughness was random, related to the aggregates. However, as it can be observed the steepest absolute slope is obtained with the chisel, being significantly different followed by tiller, roller, and control, since the roughness decay is proportional to the expected result for each tillage tool (Garcia Moreno *et al.* 2008). The results are correlated to the measurements obtained from the shadows analysis. These results seem to be mainly produced by the formation of aggregates which increase the random roughness; however an induced roughness is associated with each tillage method. The data obtained with this new method yielded results significantly correlated to the pin meter findings and chain set values, but with the advantage that the time invested in gathering field data was 4 to 20 times shorter. Image interpretation is likewise less time-consuming and the instruments needed are easier to use and more portable.

Conclusions

The aim of the present study was to develop further a method for measuring soil surface roughness that would be more reliable, reproducible and convenient to use in the field than existing procedures. Other features sought were low development and maintenance costs and adaptability to the climate and soil conditions prevailing in arid and semi-arid regions, where moisture, organic content, soil colour and weather conditions ensure the success of the method. Overall, the results for the soil surface roughness obtained from the microrelief show the following conclusions:

1. The shadow analysis gives results proportional to the expected measurements as compared to other proven methods such as pin meter and chain set methods, with the advantage of being the easiest to handle in field.
2. In the present case, SSR resulting from tilling with different tools seems to demonstrate that as the tillage tool increases the presence of aggregates, so SSR increases.
3. Further research is needed to validate shadows analysis in darker soils and higher moisture conditions than the present work.

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Significance of microtopography in a Gleysol

Daniel Okae-Anti[A] and Eunice Agyarko-Mintah[A]

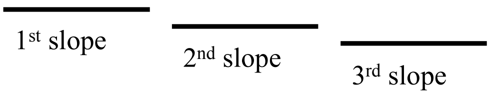
[A]Department of Soil Science, School of Agriculture, University of Cape Coast, Cape Coast, Ghana, Email dokaeant@yahoo.co.uk

Abstract
A field-based study was conducted to assess the potential of a Eutric Gleysol (WRB 2006) in sustaining the cultivation of rice. The FAO (1983) frame work of land evaluation was used to assess the actual and potential suitability of the soils. Two varieties of rice, Tox 3108-56-4-2-2-2 and Thai Jasmine rice were cultivated. Tox 3108-56-4-2-2-2 had the highest number of spikelets but the least number of panicles, while Jasmine rice had the highest number of panicles, but the least number of spikelets. Slope 3 was best suited for the cultivation of rice by virtue of moisture content. The actual suitability of the soil was rated as marginally suitable (S3fct) with fertility (f), climate (c) mainly rainfall and topography (t) as the main limiting factors. The potential suitability was suggested to be highly suitable (S1) if fertility and moisture limitations were ratified.

Key Words
Gleysol, landuse, catenary sequence, rice.

Introduction
A catenary sequence represents a sequence of soils of about the same age, derived from similar parent material and occurring under similar climatic condition, but having different characteristics because of variation in relief and drainage (Brady and Weil 2002). A typical sequence of soils formed on slopes of between 0 and 10^0 underlain by sandstones, shales and conglomerates was studied. The soils at the toe slopes and the valley bottom may have a potential for rice cultivation due to the fact that they normally have heavy textures, slower organic matter decomposition and enjoy an influx of ions from the surrounding higher lands. Physically, these soils have good water holding capacity and reduced rate of infiltration and percolation of water.

Methods
Two varieties of rice Thai Jasmine rice and Tox 3108-56-4-2-2-2 were cultivated as mono crop at the School of Agriculture Teaching and Research farm at the University of Cape Coast, Cape Coast, Ghana. The ethno-pedological soils (Udu series) occur on slopes < 2%. The soils are poorly to very poorly drained, fine-textured. An area of 15 m by 6 m was demarcated and prepared for cultivation. Four experimental plots measuring 1.5 m by 15 m were laid out in a completely randomized design (CRD). Each plot was divided into three segments according to the gradient which has a drop of about 1 cm to 1.5 cm. Each plot was randomly seeded with the test crops in four rows at 30 cm between rows (Thai Jasmine rice on two of the plots and Tox 3108-56-4-2-2-2 on the remaining two plots). Below is the schematic representation of the contour of the surface soil.



Two of the rows on each slope segment were fertilized with 90 – 40 – 40 kg N, P_2O_5 and K_2O per hectare as urea (46%), single supper phosphate (20%, P_2O_5) and muriate of potash (60% K_2O) respectively at 42 days after planting. Weed control was done manually at 14 days interval. Rainfall was depended upon mainly as a source of water supply. Measurement started twenty eight days after crop emergence and continued every 7 days till harvesting. Growth parameters such as plant height, number of tillers, number of leaves per plant, days to 50% flowering and average height at maturity were monitored and measured. The yield parameters taken were, number of panicles per plant, number of spikelets per panicle per plant and number of tillers per plant. An area of 1 m^2 was harvested at each slope for biomass yield determination. Total above ground biomass were dried at a temperature of 60 – 80 ^{0}C for three days to obtain the dry weight. Evaluation for actual and potential suitability of the soil series was done using the Simple Limitation Method.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Table 1 gives the assessment of the soil and landscape characteristics. The major land characteristics used to classify the soils were: drainage, effective depth, slope, texture, sum of basic cations (0 – 25 cm), pH, organic carbon and apparent CEC.

Conclusion

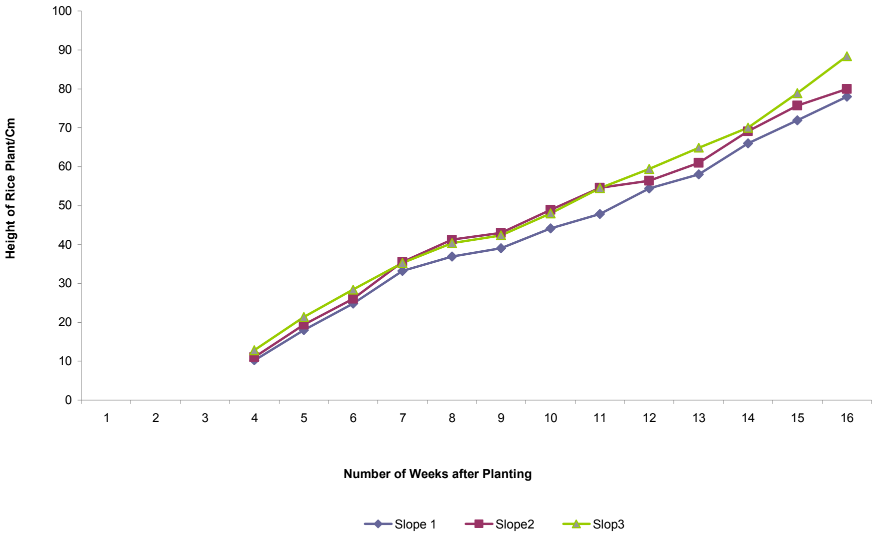


Figure 1. Effect of slope on the growth of Thai Jasmine rice.

The evaluation process was achieved by comparing land characteristics with the crop requirements. The suitability classes were determined according to the less favorable characteristics.

Table 1. Evaluation of landscape and soil characteristics.

Characteristics	Data	Suitability Classes
Topography (t)		
Slope %	0 - 2%	S1/S2
Wetness (w)		
Flooding	Seasonal	S1
Drainage	Imperfectly drained	S1
Physical soil characteristics		
Texture/Structure		
Coarse Fragment	Clay loam	S1
Depth	1%	S1
	100+	S1
Fertility characteristics		
ECEC (cmol$_c$/kg clay) (30 cm)	57.85	S1
Sum of basic cations (cmolc/kg soil)	6.86	S1
pH	5.23	S1
Organic carbon (%)	1.30%	S2/S3
Salinity and alkalinity		
EC ds/m		
ESP	0 ds/m	S1
Total landscape and	>10	S1
soil suitability rating for rice		
		S2/S3

The potential suitability of the ethno-pedological soil (Udu series) will be highly to moderately suitable for rice cultivation if fertility limitation is rectified by the provision of organic and inorganic fertilizers. However, in application, the type of fertilizer and time of application would need to be considered since these can have consequences for soil acidity, leachability and fertilizer solubility among others. Moisture and topography limitation could be ratified by the construction of bunds to collect water for irrigation or probably levelling the configuration of the land.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

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Soil and landscape constraint mapping system for land use planning

G. A. Chapman[A,B], J. M. Gray[A], X. Yang[A] and M. Young [A]

[A]NSW Department of Environment, Climate Change and Water (DECCW)
[B]Corresponding author. Email Greg.Chapman@environment.gov.nsw.au

Abstract
A series of soil and landscape constraint maps based on the relative costs of ameliorating on-site hazards as well as residual on-site and off-site risks have been developed for coastal NSW. The includes the objective ranking of multiple soil landscape qualities combined with digital elevation model technology, state-of-the-art erosion hazard modelling and Acid Sulfate Soil Risk mapping, all in a risk management setting. The resulting raster surfaces comprise 232 million pixels (25 x 25 m) and extend over 3.8 million hectares of the NSW Coast and provide unprecedented levels of spatial resolution to aid regional planning.
The results can be readily interpreted by land use planners and land managers and should contribute to environmentally sustainable land use decision making in NSW coastal regions.

Key Words
Land use planning, risk assessment.

Introduction
The effective and sustainable use of land involves a matching of site conditions with the specific requirements and potential impacts of different land uses. Significant costs to the environment and society in general may result where land is used for purposes for which it is not physically capable of sustaining. Failing to use land within its capability may have serious consequences. Common environmental impacts occurring both on and off-site include foundation instability, flooding, soil erosion and sedimentation, contamination and eutrophication of water bodies, release of acid solutions from acid sulfate soils and high maintenance costs.

In 2004 to 2006 the NSW Department of Natural Resources, working with the Department of Planning, developed a new innovative approach to capability assessment called *soil and landscape constraint assessment*.

The approach recognises the following features of land capability:

- Capability is about risk management.
- Disparate risks can be compared by assessing consequences and frequencies
- Impacts differ between land uses
- Impacts depend on site features
- Rules to assess capability can be applied on a consistent basis over large areas
- Risk and capability can be changed by human intervention
- Interventions can be costed
- Residual risks after intervention can be re-assessed.

Methods
We used the capability principles to produce a series of soil and land capability constraint maps for twelve land uses along the NSW coast. To do this we:
1) completed, digitised and strengthened Soil Landscape mapping information
2) used GIS and digital elevation model technology to disaggregate and portray previously described but unmapped soil landscape facets
3) allocated capability constraint scores to each soil landscape facet
4) combined the resulting detailed soil landscape results with similar ratings for acid sulfate soil mapping and state of the art erosion hazard prediction surfaces and
5) produced final digital and hard copy maps for each land use, giving constraint scores for each 25 m pixel.

Land uses included standard, medium density, high density and rural residential development, cropping, grazing and on-site effluent management (for trench, irrigation and pump-out systems).

Study area and data sets used
The study area encompasses 3.8 million hectares stretching from the Queensland Border to the Hunter River and then continuing along the coastal escarpment from Shell Harbour towards Eden on the South Coast.

Soil landscapes and facets
Soil Landscapes are areas that can be characterised by repeating patterns of soils and landforms. Because similar causal factors are involved in the development of soils and landscapes, it is possible to use soil landscape mapping to naturally group the soil and landscape qualities which effect land capability. In NSW 1:100,000 scale Soil Landscape mapping includes the comprehensive assessment of numerous parameters which effect land use and land management. Facets are unmapped subdivisions of soil landscapes. In many instances soil properties can be readily predicted using terrain features. Using digital elevation models we were able to disaggregate, or separately present on a map many individual soil landscape facets. This process provides an extra level of detail that cannot usually be shown directly on 1:100 000 maps.

The soil and landscape constraint assessment process
The constraint assessment approach presented here is as outlined in Chapman and Gray (2005), Gray and Chapman (2005) and Yang et al. (2005). The approach is broadly based on the United Nations Food and Agriculture (FAO) framework. The rules for assessing capability for each land use type were based on extensive literature review and were assessed by an expert panel.
The assessment process involves evaluating the combined effects of a number of key soil and landscape attributes. Key principles behind the approach are based on the risk assessment framework within the Australian and New Zealand Standards AS/NZS 4360:1999:
Risk management—'the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood'
Residual risk management— 'the remaining level of risk after risk treatment measures have been taken'. For example, large residual risk levels remain on very steep sites with erodible soils in areas subject to intense summer thunderstorms. In such areas, standard soil conservation efforts often prove ineffective.
Quantitative costings—the effective costs associated with each class of constraint are estimated, facilitating the comparison of consequences of land use change. Further detail on the costing process is given in the following paragraphs.

Constraint classes
Five classes of constraint, as applying to individual attributes, were defined:
Class 1: Very low constraint; very low residual risk; low treatment costs; straightforward or no maintenance; associated with negligible financial, environmental or social site costs; acceptable to society.
Class 2: Low constraint; associated with minor financial, environmental or social site costs; straightforward or low maintenance; low residual risk; acceptable to society.
Class 3: Moderate constraint; moderate financial, environmental or social costs beyond the standard; frequent maintenance required; moderate residual risk; marginally acceptable to society—other factors may intervene. Each attribute falling into this class represents a cost equivalent to approximately 10% of a benchmark cost
Class 4: High constraint; high financial, environmental or social costs beyond the standard; special mitigating measures are required; regular specialist maintenance; moderate to high residual risks and costs; not usually acceptable to society. Each attribute falling into this class represents a cost equivalent to approximately 30% of a benchmark cost
Class 5: Very high constraint; risks very difficult to control even with site-specific investigation and design; very high financial, environmental or social costs beyond the standard; regular specialist maintenance may be mandatory; residual risk is high; not acceptable to society. Each attribute falling into this class represents a cost equivalent to approximately 60% of a benchmark cost.

Cost allocations
The definitions include quantitative proportions of benchmark costs (including financial, environmental and social costs) associated with each class. These benchmark costs vary for different land uses or qualities. For development uses (eg, standard residential or medium density development) the benchmark costs are the estimated initial construction costs (eg, $150 000 for constructing a standard house on an ideal site). Costs may also accumulate over the life of the development (nominally 100 years). For domestic wastewater disposal, the benchmark cost is the estimated cost of establishing a reliable surface irrigation disposal system, valued at approximately $10 000.

Each constraint class (1 to 5) was assigned a 'constraint score' representing the degree of associated financial, environmental and social costs. These scores apply to individual attributes or constraints, which are added to give a total score for a particular site. Each point of the score represents an approximate additional cost of 10% of the benchmark costs as shown by Table 1.
The constraint score allows a comparison of the costs associated with the land use change at different sites.

Table 3. Scoring and costing of constraint classes (scores apply to individual attributes).

	1 Very low constraint	2 Low constraint	3 Moderate constraint	4 High constraint	5 Very high constraint
Score	0	0	1	3	6
Additional cost to land use (%)	0	0	10	30	60

Results

Using the above approach we produced raster maps showing the relative cost of achieving sustainable development for twelve types of land use. Each map covers 3.8 million hectares of coastal NSW.
An example of a constraint map produced for the Coastal Comprehensive Assessment process is shown in Figure 1.

The maps are prepared on a 25 m x 25 m raster basis with constraint scores and associated data being allocated to each cell (see Figure 1). The constraint scores shown on all maps range between 0 and > 12, with a green to yellow to red colour ramping representing the increasingly high scores. Other supporting information associated with each pixel includes:
Constraint code - the ratings applied to all constraints/attributes considered in the assessment process.

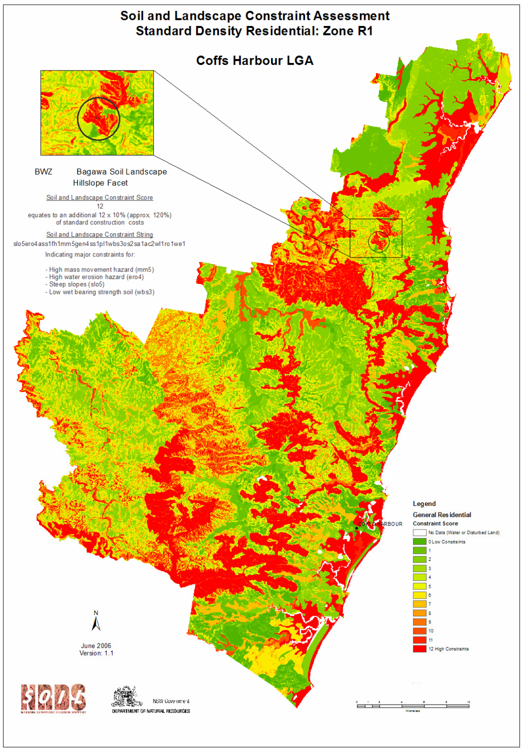

Figure 1. Soil and Landscape Constraint Assessment Map for Standard Residential Development (LEP Zone R1) for Coffs Harbour LGA.

Confidence rating – for each constraint score, ranked as: certain, confident, probable or uncertain, based on theoretical correlations and reliability of data
Unit identifier – the map number, soil landscape code and facet name to which each pixel belongs is provided. For example, 9541cuz_hillslope refers to the Murwillumbah-Tweed Heads 1:100 000 map sheet (9541), Cudgen soil landscape (cuz) and hillslope facet. Further description of the soil landscape unit may be obtained by referring to the relevant published soil landscape report.

Testing the outputs
A rigorous process of testing and review has been undertaken, including comparing results against existing capability ratings, field checking and review by soil surveyors familiar with different areas. This led to identification of minor errors and weaknesses and significant improvements in the process. The results now have a high degree of reliability, and are expected to be correct within one constraint point over 90% of the time.

Discussion and conclusions
The soil and landscape constraint assessment maps and supporting information present a clear indication of the nature and degree of soil and land constraints affecting various land-uses at different locations in the coastal area. They provide an indication of the consequences and effective economic costs of proceeding with different land use scenarios. The presentation of constraints in terms of estimated dollar costs, such as proportions of initial development costs, facilitates interpretation by land use planners and land managers. They will also be more meaningful to development proponents and the wider community.
The information is being used to:
Assist urban and regional planning processes including the preparation of planning instruments. Inform decisions relating to granting of consent to development applications and applying accompanying conditions. Identify appropriate specific use and intensity of land use Help determine project feasibility, appropriate design and likely environmental impact control measures at a particular site

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Soil condition surveillance monitoring for New South Wales

G. A. Chapman[A], J. M. Gray[A], B. W. Murphy[A], B. R. Wilson[A], G. Atkinson[A], D. T. Morand[A], J. F.Jeys[A], R. Muller[A] and B. Peasley[A]

[A] NSW Department of Environment, Climate Change and Water (DECCW). PO Box 3729 Parramatta 2124.

Abstract
In 2007-2009 2,369 soil condition monitoring permanent sites were established or contributed towards a baseline to variously monitor soil carbon, structure, pH, salinity, coastal acid sulfate soils and sheet, gully and wind erosion across New South Wales, a state in South Eastern Australia (800,000 km^2). The background, design, site selection, field protocols and evaluation methods, results and reporting products are briefly described. The current NSW soil condition index is 3.7 where 5 represents natural or reference condition and a score of one indicates complete degradation. At least one indicator on average scores below 2.5at over half of the 124 soil monitoring reporting units. Soil carbon decline is most widespread; however other indicators are of particular regional and local concern. Next steps include dialogue with catchment managers and preparation for future monitoring.

Key Words
Monitoring, condition index, carbon, indicators.

Introduction
The State Plan (NSW Government 2008) lists thirteen Natural Resource Management Targets. The targets include an improvement in soil condition and an increase in the area of land managed within its capability by 2015. Catchment Management Authorities (CMAs) have prime responsibility for achieving the targets and the Natural Resources Commission is responsible for ensuring that CMA activities are directed towards the targets. The Department of Environment, Climate Change and Water (DECCW) is responsible for surveillance monitoring, evaluating and reporting on general progress towards the targets. CMAs are responsible for their own performance monitoring. Monitoring information along with soil and land use mapping and simulation models is intended to guide natural resource management decision making by the NSW government and CMAs. Soil condition is defined here as the ability of soil to deliver a range of essential ecosystem services, including habitat for soil biota, nutrient cycling, water retention and primary plant production and is difficult to directly measure. Indicators were chosen because they are relatively easily understood, can be readily and reliably measured to detect change over time, have well understood conceptual models, are readily scientifically assessed and reported, are relatively stable within monitoring time frames and can be influenced by land management. Pilot studies were conducted for the indicators, namely: sheet and rill erosion; gully erosion; wind erosion; soil carbon; soil acidity; soil salinity; soil structure and acid sulfate soils.

Methods
In 2008 a network of permanent sites and quadrants was established across 124 soil monitoring units to assist Catchment Management Authorities and the NSW with natural resource management decision making.

Monitoring Site Selection
Because sites are expensive and few, considerable attention was given to obtaining a data array which focussed across as much of the state as possible to provide a snap shot of soil condition, paying attention to areas where change is expected and needs to be monitored as well as utility for many future uses.
For placement of permanent quadrants site selection was by a three step stratification process.

1. Within each CMA, soil monitoring units (SMUs) were selected and prioritised for monitoring by CMA and DECCW soils staff, according to: their importance, areal extent, anticipated land use pressure and number of known soils issues. SMUs are typically groups of soil landscapes and in each major catchment region up to 10 of the highest priority SMUs were established for monitoring. SMUs were typically composed of groups of related soil landscape map units (Chapman and Atkinson 1998) or closest available equivalents.
2. Selection of land holder and land management actions. CMAs were asked to select landholders who were using typical land management practices on the two most extensive land use systems within each

SMU. Within each SMU five sites were established on each of the two most extensive land use systems and where possible additional sites were established on sites of least disturbance.

3. Location of long-term monitoring sites in the most typical areas of each SMU. Site selections were confined to extensive soil landscapes and the geographic centres of their most extensive facets. Where possible the sites were paired in close proximity across land uses, controlling for landscape variables such as slope position, aspect and soil type. The conceptual value of paired sites is outlined in Eldridge *et al.* (in press).

At each site a 25 by 25 metre quadrant was established. At least one nearby permanent site marker and the south western corner were geo-located using GPS. A Soil and Land Information System (SALIS) soil profile description was undertaken to at least 50cm in the south western corner and, where practical, a steel object buried to facilitate precise future relocation using a metal detector. Each quadrant was divided into one hundred 2.5 by 2.5 metre cells. Ten cells were chosen at random using a latin square design. Within each selected cell, soil under the most typical ground cover was sampled using a 50mm diameter tube. Specimens were taken at 0-5cm, 5-10cm, 10-20cm and 20-30cm according to detailed protocols (see DECCW, in press), Sample testing is underway at the DECCW Natural Resources Laboratory at Yanco for: pH in 0.01M $CaCl_2$, LECO Carbon, Bulk Density, and Electrical Conductivity (1:5 soil:water). Other tests, including pH buffering capacity are planned from soil profile samples. Work by Wilson *et al.* (in press) suggests that the sampling method adopted in the program, involving ten replicates within a 625 m^2 quadrant, provides an accuracy within 15 per cent of the true mean within 90 per cent of the time, at least for pH, carbon and bulk density. This is considered sufficient accuracy to determine change thresholds of 0.2 per cent carbon and 0.2 of a pH unit at more than 90 per cent of sites.

In all over thirty four thousand samples were collected to measure Carbon and pH; a modified version of the Visual Soil Assessment Shepherd (2000, 2007) and a further 1700 samples were used to assess soil structure at 850 characterised sites. Landholder surveys to both assess land management within capability (Gray *et. al,* in press), and to ascertain ground cover management practices for sheet erosion modelling were collected for 500 of the sites. In addition 128 detailed and 1200 broad-scale gully erosion sites; 40 acid sulfate soil sites; 23 dust particle sensors; eight detailed salinity study areas and thousands of mapped saline discharge sites were established or utilised. Sheet erosion and wind erosion were assessed using the Revised Universal Soil Loss Equation (Renard *et al.* 1997) and computational Environmental Management System (Shao *et al.* 1996) models.

Evaluation and Index Development

All thirteen natural resource management monitoring themes were requested to provide where possible condition ratings using a five class index, where class five represents reference condition and class one signifies complete degradation (Table 1). Consequentially a five class soil condition classification was developed for each indicator, for example as shown for soil acidity, in Table 2. Reference condition boundaries were determined for each SMU from literature review and undisturbed land use SALIS database values for the same soils within equivalent climates and parent material zones. Functional threshold values were also used to define other class boundaries.

For each site each relevant indicator was allocated a condition class. Soil Condition Indexes were derived by averaging values for all sites within SMUs, CMAs and ultimately the state. Ratings of averaged values are shown in Table 2.

Table 1. Assignment of soil acidity condition ratings.

Soil acidity condition class	5	4	3	2	1
Soil acidification zone		**expected natural pH for the zone**			
a	**>4.75**	**Not applicable**	**<4.75**	**<4.5**	**<4.1**
b	**>5.0**	**>5.0**	**<4.75**	**<4.5**	**<4.1**
c	**>5.3**	**<5.3**	**<4.75**	**<4.5**	**<4.1**
d	**>7-5.5**	**<5.5**	**<4.75**	**<4.5**	**<4.1**
e	**>7.1-5.8**	**<5.8**	**<4.75**	**<4.5**	**<4.1**
Class boundaries Functional thresholds		**mid point from 5 to 3 (noticeable decline)**	**Al soluble becomes soluble**	**Mn becomes soluble**	**Clay dissolution**

Table 2. The NSW Soil Condition Index.

4.6 – 5.0	Very good	No loss of soil function. Either no deterioration or an improvement on reference condition.
3.6 – 4.5	Good	Slight loss of soil function. Noticeable but not significant deterioration against reference condition.
2.6 – 3.5	Fair	Noticeable loss of soil function. Noticeable deterioration against reference condition.
1.6 – 2.5	Poor	Significant loss of soil function. Considerable deterioration against reference condition.
<1.5	Very poor	Profound loss of soil function. Severe deterioration against reference condition.

Further details concerning the program are in Chapman *et. al* (in press).

Results

Laboratory testing is continuing, however preliminary results involving at least one soil core sampled from each site for carbon and pH were used to prepare the *NSW 2009 State of Environment Report* (DECCW, in prep). On a state wide basis, overall index for soils in NSW was assessed by MER as 3.7, indicating overall "fair" to "good' soil condition. On average, there has been a noticeable and moderate decline in the condition of NSW soils relative to their condition in the natural "reference condition". This is interpreted as meaning that on average there has been a moderate loss of NSW soils to provide ecosystem services.

Some parts of the state and some particular soil condition indicators, however, have overall poorer condition, and a significant loss of soil function. These specific areas and indicators have lower soil condition indices, indicating "poor" or "very poor" condition, with a "significant" or "profound" loss of soil function and a substantial deterioration against the natural reference condition. The results suggest that on a state-wide basis, low organic carbon is the dominant issue of concern (see Figure 1), with organic carbon, soil structure sheet erosion, salinity, and soil acidity also being of significant concern.

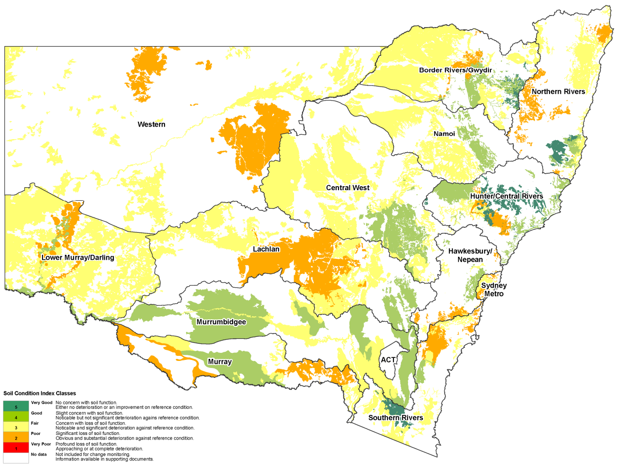

Figure 1. Soil Carbon Condition for NSW

Organic carbon has been assessed as the most serious issue of concern across NSW. Its overall current condition is fair with an index of 3.2; and 29 (23%) of SMUs have indices at or below 2.5 (poor). It is a significant issue of concern in 5 of the 13 CMA regions. Preliminary analysis of SMU condition scores for the indicators suggests that there are three clusters of correlated condition scores: Sheet erosion, soil salinity and soil acidity are significantly positively correlated. As would be expected soil structure and soil carbon are significantly positively correlated. The negative correlation of wind erosion with both salinity and acidity is likely to be related to spatial factors.

Discussion and conclusions

The correlations of soil condition indicators appear to be linked spatially and relate to well established soil science and landscape processes and require further investigation. Identification of clusters of degraded soil indicators, or land sickness syndromes has implications for catchment planning, land management and monitoring program design. Whilst the soil condition index may be useful to compare soil condition with similarly scaled indexes from other themes, the process of averaging results in a central tendency which belies the fact that many sites are in poor or very poor condition. We recommend a serial process of data investigation and dialogue with CMA decision makers to make best use of the information.

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Soil Fertility Evaluation in Negara Brunei Darussalam

Gerard Grealish[AD], Anthony Ringrose-Voase[B], and Rob Fitzpatrick[CD]

[A] CSIRO Land and Water, Urrbrae, South Australia, Australia, Email Gerard.grealish@csiro.au
[B] CSIRO Land and Water, Canberra, Australian Capital Territory, Australia, Email Anthony.Ringrose-Voase@csiro.au
[C] CSIRO Land and Water, Urrbrae, South Australia, Australia, Email Rob.fitzpatrick@csiro.au
[D] The University of Adelaide, Earth and Environmental Sciences, South Australia, Australia

Abstract
A goal of Negara Brunei Darussalam Department of Agriculture is to increase agricultural production and reduce dependence on imported food products by increasing the area of land used for agriculture and by increasing productivity on existing agricultural land. This consultancy project provided supporting information by assessing the soil characteristics and their suitability for a variety of crops and provided recommendations for profitable and sustainable land management. This project generated a number of soil evaluation products that assisted with providing consolidated information and transfer of knowledge to assist with improved land use decision making for policy makers, advisory officers, and farmers. The products included: soil data for 24 soil types, maps, soil identification key, field manual for soil type identification (in English and Malay), toposequence cross-sections, database and land information system, land evaluation calculator, suitability assessment for 69 crops, acid sulfate soil identification, fertilizer and lime calculator, and identification of management options. This paper presents key features for some of these products that were successfully used to communicate and deliver soil evaluation information targeted to the different levels of users in Brunei.

Key Words
Soil identification key, suitability, limitation, toposequence cross-section.

Introduction
Negara Brunei Darussalam is a small country of 5765 square kilometres, located on the north of Borneo Island next to the South China Sea and land borders with Malaysia. Rainforest covers about 80 percent of Brunei's land and its capital city, Bandar Seri Begawan is next to the Brunei River. Historical soil survey information was of limited use to address the current soil evaluation and fertility guidance required because not all soils of interest were investigated and the soils that were described and analysed did not provide sufficient data for evaluation of the current issues. Most current knowledge about the soils and their behaviour resided with some farmers and agricultural advisors obtained through experience and this information has not easily been captured to allow transfer of information elsewhere.

To achieve the goal of increasing agricultural production and reduce dependence on imported food products, soil suitability and limitations needed to be identified to determine appropriate management. Specific questions that this project provided data for included:
Evaluation of new areas for agricultural development
- Can the soil be sustainably developed for agriculture?
- Is the soil suitable for the intended crop?

Evaluation of existing areas of agricultural land
- Is the soil suitable for the crops being grown?
- What are the alternative crop options that the soil is suitable for?
- What are the major soil constraints limiting cropping and can these be managed?

To assist the Bruneian users with obtaining answers to the above land evaluation questions, this project presented information and assessments in a format that could readily be used to guide decision making. This poster paper provides a summary description of the products used to communicate and deliver soil information.

Methods
The soil fertility evaluation project consisted of a number of inter-related steps that included:
- Data collection – extraction of relevant historical soil data and maps, conducting field soil surveys and sampling of soils, laboratory analysis to provide data on soil chemical and physical characteristics,

- Compilation of soil information – identifying key soil types, generating soil maps, developing relationships between the soil and key features including landscape.
- Evaluation of the soil - using the Fertility Capability Classification (Sanchez *et al.* 2003).
- Evaluation of the crops for each soil type – using literature data to provide guidance with regard to crop behaviour for different soil properties, a number of the tropical fruits and crops had limited information to draw on and therefore expert and local experience was used.
- Linking soil types with crops – evaluation to determine suitability and limitations of the soils for each crop.
- Acid sulfate soil investigations – soils of concern sampled and analysed to evaluate the magnitude and extent of this soil hazard.
- Reporting – generation of detailed technical reports, soil information system, fertility calculator, field manual and training of advisory staff in the use of the project soil outputs.

The field survey described 295 soil profiles in 29 different areas and across a variety of landscapes, soil layers from 60 profiles underwent laboratory analysis to determine selected chemical and physical properties. The assessment identified 24 soil types that were then evaluated for their suitability to grow 69 crop types ranging from vegetables, grasses, rice, and fruit trees. Significant soil limitations identified included: water logged soils, hill-slope soil erosion, acid sulfate soils, excessive or insufficient fertilising of soils. The project generated a significant volume of information that required compiling into products that people who are not experts in soil identification and evaluation could use to assist them with land evaluation.

Results

The results presented in this poster paper are examples of project products generated as part of the soil fertility evaluation in Negara Brunei Darussalam. The products were used to provide soil information to people who are not specialist in identifying and interpreting soil data and therefore the products were in a simple and easily understood form that would assist them with evaluating land use suitability and limitations, and to provide guidance for management.

Soil Identification Key

The classification, morphology and extent of the soils are described in Grealish *et al.* (2007a, 2007b). Soils were initially classified according to Soil Taxonomy (Soil Survey Staff 2003), which allowed valuable information on soil and crop behaviour to be transferred to the Brunei soils to support the soil and crop evaluation. To assist people who are not soil experts to identify soils, a simplified soil identification key was developed and tested with agricultural advisory staff and farmers. The identification key uses plain language terms and simple soil descriptive questions to guide the user systematically through the key until a soil type is arrived at; the upper level of the key is shown in Figure 1. Further questions at lower levels in the key are used to separate out the soil subtypes.

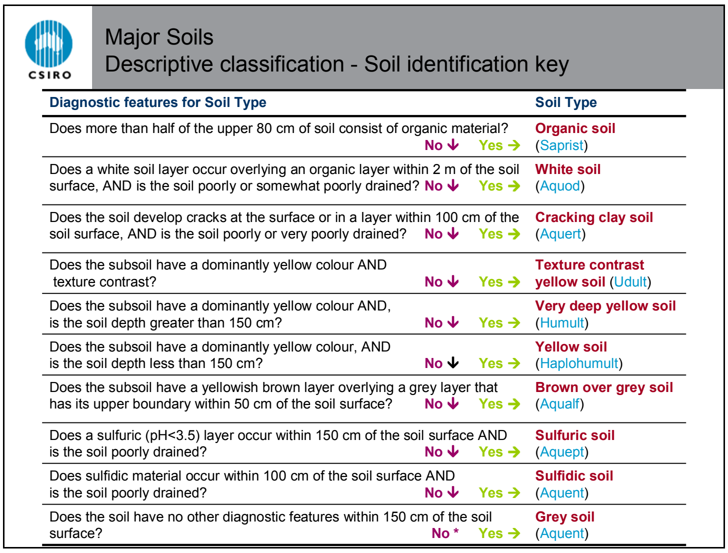
The plain language soil type and subtype names, corresponds to the major Soil Taxonomy Suborder and Subgroup classes found in the survey. These names provide assistance in understanding the intent and general nature of the soils classified using Soil Taxonomy. For example, the four acid sulfate soil types in the Key are: (i) Organic Soils, (ii) Cracking Clay Soils, (iii) Sulfuric Soils and (iv) Sulfidic Soils (Grealish *et al.* 2008). These are further sub-divided into eleven subtypes at a lower level in the identification key based on depth to sulfuric/sulfidic horizon; firmness; and drainage (waterlogging).

Soil Property Interpretation

An evaluation of the soil property data held in the soil information system was conducted using an adapted Fertility Capability Classification (Sanchez *et al.* 2003). The data and evaluation was summarised to allow users to quickly identify important soil features, the main limitations and determine what crops were suitable as shown in Figure 2.

Toposequence Cross-Sections

The project recognised that farmers and agriculture advisors identified and understood soil distribution on their farms by relating the soil type to positions in the landscape, and that they were more familiar with this relationship than interpreting a soil map. To assist with conveying the soil distribution and linking that to crop suitability, simplified soil-landscape cross-sections with tabulated crop suitability information was used (Figure 3).



Major Soils
Descriptive classification - Soil identification key

Diagnostic features for Soil Type	Soil Type
Does more than half of the upper 80 cm of soil consist of organic material? No ↓ Yes →	Organic soil (Saprist)
Does a white soil layer occur overlying an organic layer within 2 m of the soil surface, AND is the soil poorly or somewhat poorly drained? No ↓ Yes →	White soil (Aquod)
Does the soil develop cracks at the surface or in a layer within 100 cm of the soil surface, AND is the soil poorly or very poorly drained? No ↓ Yes →	Cracking clay soil (Aquert)
Does the subsoil have a dominantly yellow colour AND texture contrast? No ↓ Yes →	Texture contrast yellow soil (Udult)
Does the subsoil have a dominantly yellow colour AND, is the soil depth greater than 150 cm? No ↓ Yes →	Very deep yellow soil (Humult)
Does the subsoil have a dominantly yellow colour, AND is the soil depth less than 150 cm? No ↓ Yes →	Yellow soil (Haplohumult)
Does the subsoil have a yellowish brown layer overlying a grey layer that has its upper boundary within 50 cm of the soil surface? No ↓ Yes →	Brown over grey soil (Aqualf)
Does a sulfuric (pH<3.5) layer occur within 150 cm of the soil surface AND is the soil poorly drained? No ↓ Yes →	Sulfuric soil (Aquept)
Does sulfidic material occur within 100 cm of the soil surface AND is the soil poorly drained? No ↓ Yes →	Sulfidic soil (Aquent)
Does the soil have no other diagnostic features within 150 cm of the soil surface? No * Yes →	Grey soil (Aquent)

Figure 1. The upper level of the Soil Identification Key, showing linkage between Soil Taxonomy and local common name classification.

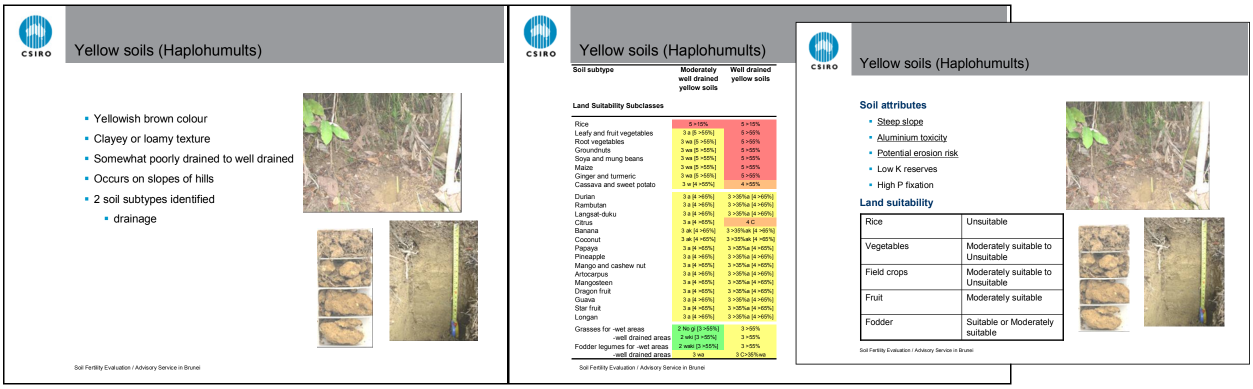
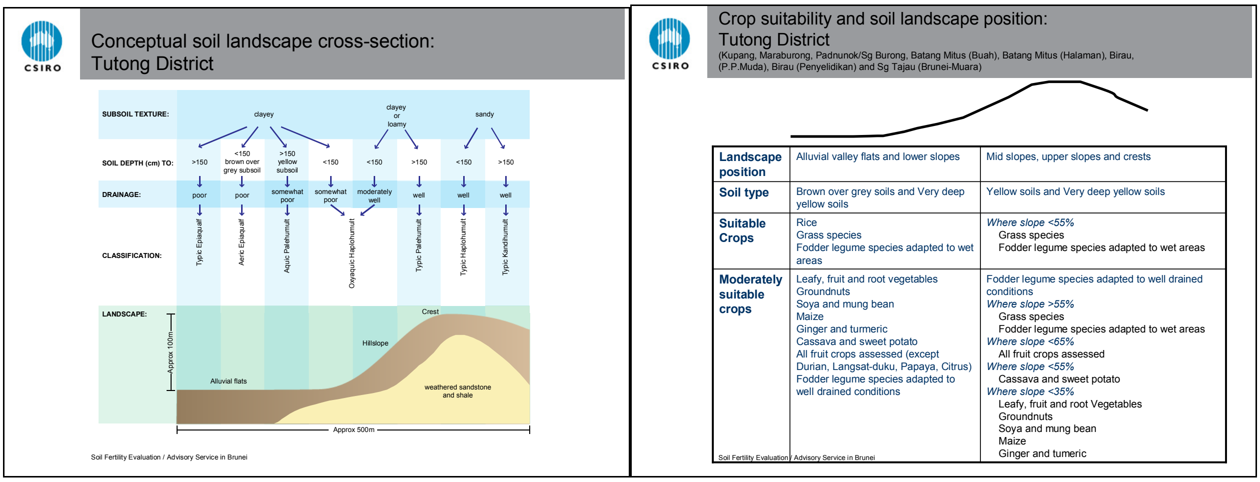


Figure 2. Example of soil type description, capability classification for crops and key soil attributes.



Landscape position	Alluvial valley flats and lower slopes	Mid slopes, upper slopes and crests
Soil type	Brown over grey soils and Very deep yellow soils	Yellow soils and Very deep yellow soils
Suitable Crops	Rice Grass species Fodder legume species adapted to wet areas	*Where slope <55%* Grass species Fodder legume species adapted to wet areas
Moderately suitable crops	Leafy, fruit and root vegetables Groundnuts Soya and mung bean Maize Ginger and turmeric Cassava and sweet potato All fruit crops assessed (except Durian, Langsat-duku, Papaya, Citrus) Fodder legume species adapted to well drained conditions	Fodder legume species adapted to well drained conditions *Where slope >55%* Grass species Fodder legume species adapted to wet areas *Where slope <65%* All fruit crops assessed *Where slope <55%* Cassava and sweet potato *Where slope <35%* Leafy, fruit and root Vegetables Groundnuts Soya and mung bean Maize Ginger and tumeric

Figure 3. Example of use of landscape cross-section, identifying soils in different landscape position and the related crop suitability

Soil Fertiliser and Lime Calculator

Soil analyses showed excessive fertilizer use in some areas and in other areas it was found that insufficient fertilizer was being applied. To improve the application of nutrients to the soil for a specific crop, a calculator was developed for Brunei conditions. The calculator was targeted for use by agricultural advisors who make recommendations to farmers. The soil fertiliser calculator allows different fertiliser scenarios to be modelled as well as determination of the most suitable fertiliser approach for the soil and crop conditions (Wong *et al.* 2007).

Reports and Field Manual
The project generated a number of Technical Reports (e.g. Fitzpatrick *et al.* 2008; Grealish *et al.* 2007a,b, Ringrose-Voase *et al.* 2008; Wong *et al.* 2007), but for use by farmers a field manual was prepared in English and Malay. The manual provides simplified descriptions of soil types, pictures, and evaluation for crop suitability and management.

Conclusion
Key features for the successful delivery of soil evaluation information included:

- A soil identification key specific to the soils of the region and written in plain language for people who are not experts in soil identification could work through to determine the soil type.
- Simplified landscape cross-sections that showed the expected positions of the soils and their distribution as people working on the land were familiar with topographic positions
- An identification key to recognise acid sulfate soils occurrence and evaluated soil data to provide suggested management options.
- Soil fertilizer and lime calculator established for the Brunei soil conditions, with an easy to use input interface and outputs of recommended nutrient requirements
- A soil land information system and detailed technical reports with soil property data, maps and a comprehensive assessment of 69 crops, including the clear rationale behind the assessments should users want more detailed information.

Acknowledgements
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Soil quality assessment of Oxisols and Ultisols: The roles of site-specific factors

Anna M. Makalew[A], Bambang H. Sunarminto[B], Woerjono Mangoendidjojo[B] and Didik Indradewa[B]

[A]Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru, Indonesia, Email annmaak@yahoo.com.
[B]Faculty of Agriculture, Gadjah Mada University, Yogyakarta, Indonesia.

Abstract
Soil quality (SQ) can change due to management practices and the inherent properties of soil. Designed for enabling sustainability of agriculture, the objectives of this study are to (i) examine the roles of site-specific factors of Oxisols and Ultisols, (ii) determine the soil quality index of Oxisols and Ultisols in order to see the change in SQ due to management practices. Three varieties of corn, Local Kima, Sukma Raga, and Bisi-2 were grown in a multilocation experiment on a Typic Hapludox (CLTH), Plinthic Kandiudults (CLPK), and Plinthic Hapludoxs (CLPH) in Panyipatan Tanah Laut South Kalimantan Indonesia. The 17 attributes of soil sampled from 0 – 15 cm soil surface were statistically analyzed using the multivariate analysis of variance (manova) followed by principal factor analysis (PFA) of SAS 6.12 (SAS Inst. 1996). Combined with an expert system of the Soil Management Assessment Framework (SMAF), step by step data reductions of manova and anova($\alpha \leq 0.05$), followed by factor analysis was used to determined the amount of variance explained by each factor (eigenvalue ≥ 1). The indicators included in the SQ equation are bulk density (BD), available water capacity (AWC), total organic carbon (TOC), soil pH, and soil P. The soils showed different relationships due to the difference of site-specific factors.Used the SMAF equation, it is found that the SQ index of CLTH, CLPK, and CLPH in Panyipatan are respectively 74.46, 69.47, and 54.00.

Key Words
Soil quality, oxisols, ultisols, site-specific factor.

Introduction
Soil quality (SQ) is the capacity of soil to function, within natural and managed ecosystem boundaries, to sustain plant and animal productivity, maintain and enhance water and air quality, and support human health and habitation (Karlen *et al.* 1997; Andrews *et al.* 2004). Understanding SQ means assessing and managing its quality so that it functions optimally now and for the future. SQ can not be measured directly; therefore it needed indicators to be evaluated. To determine the SQ index, indicators need to be scored. Scoring function depends also on site-specific factors. The indicator changes can be used to determine whether SQ is improving, stable, or declining. The objectives of this study are to (i) examine the roles of site-specific factors of Oxisols and Ultisols, (ii) determine the soil quality index of Oxisols and Ultisols in order to see the change of SQ due to management practices

Methods
The SMAF (Andrews *et al.* 2004) follows three basic steps: Indicators selection, indicator interpretation, and integration to SQ index value.

Table 1. Potential management goals and associated soil functions and SQ indicators for each function.

Management goals	Supporting soil function	Indicator	Criteria for selection of indicator
Productivity	Nutrient cycling	pH; P; TOC	Always suggested under this function; Organic amendment comparison or productivity goal
Waste recycling	Water retention	AWC, pH; BD; TOC	Always suggested under this function; Clay texture + practice comparison;
Environmental protection	Physical stability and support	BD; TOC	Clay texture + practice comparison
	Filtering and buffering	-	-
	Resistance and resilience	TOC	C change assessment or organic amendment comparison
	Biodiversity and habitat	-	-

Source: Modified and combining Table 1 and Table 2 of Andrews *et al.* 2004

Indicator selection
To generate minimum data set (MDS), the SMAF uses a series of decision rules. The selection criteria of decision rules are the management goals associated soil functions, like maximizing productivity, waste recycling, or environmental protection; and site-specific factors, like region or crop sensitivity. These rules (Table 1) serve as an expert system to select appropriate SQ indicators (Bellocchi *et al.* 2002; Andrews *et al.* 2004). The user is asked to select four to eight indicators with at least one indicator from each function. In this study only five indicators are selected.

Indicator interpretation
Interpretation of indicators includes transformation of each MDS indicator to unit less value using nonlinear scoring curve (Andrews *et al.* 2004). The SMAF scoring curves consist of algorithms, which are quantitative relationships between empirical values of measured indicators and normalized scores, reflecting the performance of ecosystem service(s) or soil function(s). The algorithms (Andrews *et al.* 2004) were constructed using a curve fitting program, Curve Expert v. 1.3. It is assumed that the relationship between a given indicator and the soil function(s) it represents hold relatively constant among systems. This relationship determines the shape of curve or the algorithm equation of an indicator. An indicator score of 1 represents the highest potential function for that system. The SMAF assumed that the expected range for each indicator will vary according to site-specific controlling factors, such as climate or inherent soil properties.

Integration into an index
The SMAF integrates all indicator scores into the single, additive index value. This value is considered to be an overall assessment of SQ, reflecting management practice effects on soil functions. The SQI equation is:

$$SQI = \sum_{i=1}^{n} S_i \text{ -------- x } 100 \qquad (1)$$

Th e indicator value and n represents the number of indicators in the MDS.

Experimental design, sampling, and statistical analysis
In multilocation experiment in randomized completely block design with 3 blocks at each site, 3 varieties of corn, Local Kima, Sukmaraga, and Bisi-2 were planted in 3 nearly level upland locations stratified based on the differences of soil subgroups of Oxisols and Ultisols: Tipyc Hapludoxs (CLTH), Plinthic Kandiudults (CLPK), and Plinthic Hapludoxs (CLPH) in Panyipatan Tanah Laut South Kalimantan Indonesia. One month prior to planting, soil was plowed and harrowed; chicken manure was applied to each site on the rate of 2 ton/ha. During the planting season, urea, SP36 and KCl were applied twice on the 15 days and 37 – 40 days after planting. Soils were sampled 3 times from 0 – 15 cm, before planting, at the time of silking period, and on harvesting, and were analyzed using standard methods of soil analysis. Soil texture was measured using the Bouyoucos hydrometer method. BD is the ratio of oven dried soil (mass) to its bulk volume measured from an undisturbed soil sample. AWC, the amount of water held between field capacity and wilting point is calculated between 1/3 bar – 15 bars. Other soil analysis carried out are the organic-carbon (TOC), nitrogen (N), potential P_2O_5 and K_2O_5 (25 % HCl extraction), available soil P (Bray extraction), exchangeable cations, and cation exchange capacity (1 N NH_4OAC, pH 7.0). Corn leaves were also sampled at the silking period and analyzed for N, P, and K.

Statistical analysis was performed using UNIVARIATE, GLM, and PFA of SAS 6.12 (SAS inst. Inc 1996). These variables were checked for homogeneity and normality. Assessment of SQ was achieved by examining soil attributes simultaneously (Brejda *et al.* 2000). Multivariate analysis of variance (MANOVA) was first used to determine whether there were significant management effects on the 17 soil variables. Wilk's lambda and F statistic were examined to test the hypothesis of no overall treatment effect. The soil variables with p value ≤ 0.05 and CV ≤ 40 were retained then examined using PFA to test the (null) hypothesis of no common factors. Factors with eigenvalue > 1 were retained for interpretation using rotation. Combined with the expert system table of SMAF, SQ indicators MDS were determined. To examine the roles of site-specific factors, treatment means for observed and scored indicators were compared using anova with regions (soil subgroups) and varieties as independent variables.

Results
The minimum data set, MDS
The result of the first step manova performed to observe the effects of regions (soil subgroups) and varieties

on 17 soil variables sampled on 27 experimental points were (1) there was no interaction between regions and varieties, and TOC was significantly affected by regions and corn varieties, whilst the other soil variables are significantly affected only by the regions; (2) six variables NO3, NH4, exch. Al, Fe, exch. K, and variable Na had p values > 0.05 and CV >40 %; therefore, they were not considered for further analysis; (3) eleven variables: BD, AWC, TOC, N, pH, P, K, Pbray1, Ca, Mg, and Cations will be subjected to factor analysis.

Factor analysis
There are four eigenvalues 3.3220, 2.6268, 1.5131, and 1.1332, which together account for 78.14 % of the standardized variance. Four factor retained on the basis of the eigenvalue-greater-than-one-rule is rotated (equamax). Brejda *et al.* (2000a), named each factor based on their loadings. In this study, based on their loadings, the first factor was termed the soil P, the second factor named soil Pbray, the third factor named soil K , and the fourth factor named soil N. The four factors and soil attributes from which they are comprised based on their correlations can be seen in Table 3.

Table 2. SQ factors and the soil attributes that comprises these factors.

Factor 1	Factor 2	Factor 3	Factor 4
P (soil)	*Pbray (Fertility)*	*K (Fertility)*	*N (Organic matter)*
P	Pbray1	K	N
AWC	Soil pH	Exch. Mg	
TOC	Exch. Ca		
BD			

Expert opinion, SMAF
The second method to determine MDS is based on expert opinion, SMAF. Table 1 act as an expert system. Combining these two methods, the MDS indicator includes BD, AWC, TOC, soil pH, and soil Pbray1.

Indicator interpretation and the site-specific factor roles
The expected range for each indicator and site-specific factor values were decided based on SMAF (Andrews *et al.* 2004), and research (Djaenuddin *et al.* 1994; Grossman *et al.* 2001; Diaz-Zorrito *et al.* 1999: 91; USDA 1966; Walf and Baker 1985; and Bappedal PPLH UGM, PSSL UGM 2000).

Table 3. MDS indicators observed and scored of three soil subgroups CLTH, CLPH, and CLPK in Panyipatan District South Kalimantan Indonesia.

Indicator	CLTH		CLPK		CLPH	
	Observed	Scored	Observed	Scored	Observed	Scored
BD	1.08	0.98	1.20	0.79	1.23	0.72
AWC	15.00	0.66	9.78	0.49	12.71	0.59
TOC	2.55	0.70	2.21	1.00	1.88	0.41
pH	4.46	0.77	4.19	0.57	4.33	0.62
Pbray1	6.39	0.61	6.45	0.62	4.52	0.37

To examine the roles of site-specific factors, treatment means for observed and scored indicators were compared using anova with regions (soil subgroups) and varieties as independent variables.
BD is assigned a less-is-better function because of the inhibitory effect on root growth and porosity; the site-specific factors are texture and mineralogy (Grossman *et al.* 2001). AWC is a more-is-better function based on its roles of water availability for crop requirement, nutrient solubility, and biological activity; the site-specific factors are texture and inherent organic matter (Gregory *et al.* 2000). TOC is a more-is-better function based on its roles in soil fertility, water partitioning, and structural stability; the site-specific factors are inherent organic matter, texture, and climate (Herrick and Wander 1998). Variation of mid-point optimum or Gaussian function was used for soil pH based on crop sensitivity and effects on nutrient availability; the site specific factors are crop (Smitt and Doran 1996) and land suitability level. The curve of soil P , according to Maynard and Pierzynski (Andrews *et al.* 2004) is mid-point optimum based on crop response and environmental risk; the site-specific factors are crop, TOC, texture, and the test procedure.

Determining soil quality index, SQI
Using Equation (1) the SQI of CLTH was 74.46 > CLPK is 69.47 > CLPH 54.00.

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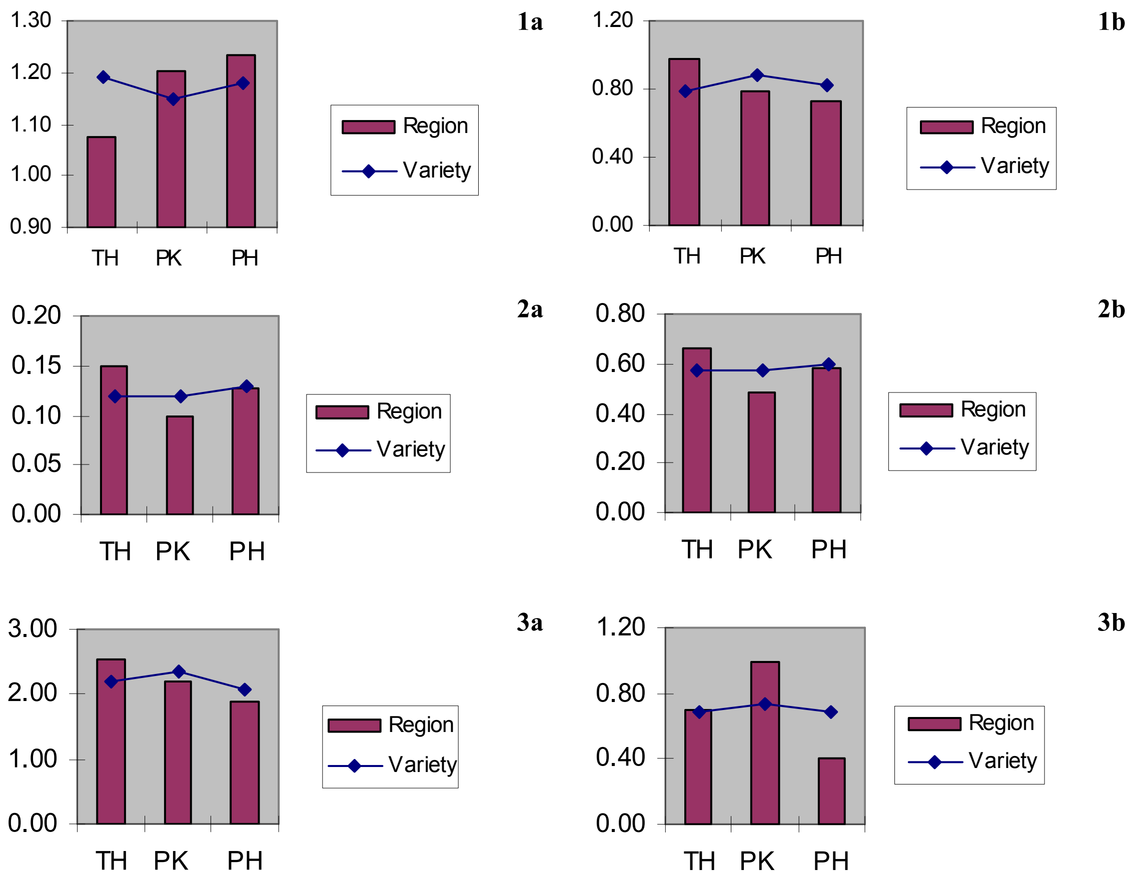

Figure 1. Shape of treatment mean variables for BD observed (1a), BD scored (1b), AWC observed (2a) AWC scored (2b), TOC observed (3a) and TOC scored (3b).

Conclusions

SMAF is considered an appropriate tool for assessing management effects on SQ because the framework encompasses productivity and environmental goals. It is also flexible and especially sensitive to the differences of site-specific factors, such as inherent soil and climate. Although analysis factor (PFA) can statistically support the SMAF expert system, further research is needed to avoid the redundancy of SQ indicators in MDS due to the correlations among soil attributes. The study found that in general, the most sensitive indicator in MDS is soil organic matter due to its roles and functions as dynamic and inherent SQ.

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Land Capability, Suitability and Vocation in Venezuela

Juan Comerma

Pequiven- Palmichal, Carabobo, Venezuela. Email fliacomermas@cantv.net

Abstract
In Venezuela, the terms Land Capability, Suitability and Vocation, have been used indistinctly to recommend the most appropriate land use for a given soil. Nevertheless, each term has and should play a clear role in land use planning. Land Capability shows the limitations and potentials for a general agricultural land use, going from a very ample to a limited number of uses, and may serve as a nationwide indicator of land quality. On the other hand, Suitability, especially with the scheme of Land Evaluation of FAO, has been used to ascertain the degree of agroecological and socioeconomic adequacy of a specific use, or land utilization type, for each land unit. Finally, Vocation is being defined as the selection of the most appropriate use, among the suitable ones, fitting the present conditions of development. For that, we combine the suitability with other political, social, economical and infrastructural variables. In this paper a proposal for its determination is presented.

Key Words
Soil interpretation, land evaluation, land use planning

Introduction: Concepts and Experiences on Capability and Suitability

The term Land Use Capability, introduced in 1960 by the Soil Conservation Service in USA, (Klingebiel and Montgomery 1961), has been widely used specially in the American Continent. In Venezuela, it was adapted to the national conditions (Comerma and Arias 1971), introducing among other things: a semi quantification of the parameters used for Topography (T), Erosion (E), Soil (S) and Drainage (D), within each Bioclimatic area of the country, as well as within certain levels of technology. The result was a system that can be used and correlated at national level. These improvements have been applied and adjusted, and offer an adequate comparison of the quality and limitations of our agricultural lands. Table 1, shows an example taken for the Tropical Dry Forest, one out of 22 bioclimates present in the country, and at a common technological level. In there, we can see the combination of parameters of T, E, S and D established for each Class (I to VIII). For a more detailed level, parameters like slope (p), micro relief (m), grain size distribution (g), rockiness (r), depth (h), salinity (s), fertility (f), hydraulic conductivity (c), internal drainage (n), external drainage or water logging (a) and flooding (i),are used. The values assigned or permitted in each class for each parameter and reflecting ranges of slope, erosion, texture, fertility, etc. can be consulted in the original paper (Comerma and Arias 1971).

Table 1. Example of Land Capability used in Venezuela for the Tropical Dry Forest.

Bioclimate	Rainfall (mm)	Temperature (ºC)	ETP/P	Altitude m
Dry Tropical Forest	1.000 - 1.800	22 – 29	0,9 - 2,0	400 - 1.000

	T		E	S						D		
Class	p	m	e	g	r	h	s	f	c	n	a	i
I	1	1	1	2 - 4	1	1	1	1	3	3, 4	3 - 5	1
II	1	1	1	2 - 4	1	1	1	2	3	3, 4	3 - 5	1
III	2	2	2	1 - 4	1	2	2	3	2 – 4	2 - 4	3 - 5	1
IV	3	2	2	1 - 4	2	2	2	3	2 – 4	2 - 4	2 - 5	2
V	3	2	2	1 - 4	2	2	2	4	1 – 4	2 - 4	2 - 5	3
VI	4	3	3	1 – 4	3	3	3	4	1 – 4	1 - 4	1 - 5	4
VII	5	3	4	1 - 5	4	4	3	5	1 – 5	1 - 4	1 - 5	4
VIII	6	4	4	1 - 5	4	4	4	5	1 – 5	1 - 4	1 - 5	4

The idea being that each combination of parameters is done as a function of the specific climatic condition, with special consideration of its interactions with soil and topographical conditions. Like that Table, other sixteen Tables were constructed, representing the main bioclimatic regions of the country. The Classes show the amplitude of crops, i.e. Class I can be used for many cash crops, pastures and forest plantations. Going to higher classes, the limitations increase, and consequently the number of options decreases. The Subclasses, whether general (T,E,S,D) or specific (p, m, e, g, f, etc) indicate the main limitations, serving in this way as an indicator of the quality of the land, and allowing a national comparison of agricultural lands in the Country. This system has been applied in Venezuela since 1971 covering over 90% of our territory.

Nevertheless, this type of interpretations does not offer the necessary specificity to know if a given area is adequate for Corn or Sugar Cane, or a given pasture or a forest plantation, and this is required to be known when a given agricultural development plan for a region or a farm is studied. For these last requirements, the FAO offered a Framework of Land Evaluation (FAO 1976) and later on more specific schemes for rainfed, irrigated forestry and pastures, to establish the degree of agroecological and socioeconomic suitability for each Land Utilization Type (LUT or a given crop with a certain technological combination) for each land unit. The result of this kind of land evaluation provides, for each land unit, a menu of options of different uses with its degree of suitability. The application of these procedures has been applied to over 60 million hectares in Venezuela, offering precise criteria to decide, on a quantitative basis, about which uses are more appropriate and which ones should be discarded.

But recently, in Venezuela with the new Law of Land and Agricultural Development (Venezuela 2001), the term Vocation was introduced, pretending to assign the best specific crop for each land class and consequently, to determine if the present land use is adequate or if the land could be taxed or even expropriated. But to establish the Land Vocation there does not exist a precise methodology, and for this purpose a proposal is presented here trying to use a scheme as close as possible to the new Law.

Proposal of land use Vocation.

After examining the last modifications of the Regulations of the Law (Venezuela 2005), a definition of Vocation is found, stating as follows: "Vocation results from the interaction of physical factors (soil, climate, topography and erosion), technological, socioeconomic, cultural, and the agroecological requirements of the crops, that determine the assignment of the agricultural uses (vegetables, fisheries, husbandry and forestry) under sustainable conditions for the production units " The assignment is done after presenting a Table in which for each Class of Land (I to VIII) correspond specific uses. For example, for Class I Vegetable crops and legumes are noted; additionally, for class II are mentioned cereals, bananas, roots and tubers and certain tropical plantations.

In article 4 of this Regulation, more details are given, pointing out that the classification of Vocation results from the combination of: **"**Land Capability of the land; Agroclimatic characteristics, Agroecological requirements of the crops; Availabilty of inputs (labor, mechanization, seeds and agrochemicals); Infrastructure and supporting services as roads, irrigation and drainage facilities**,** technical assistance and centers for storage and processing; availability of hidrological resources; importance of the crops in the National and Regional agricultural Plan**."**

This proposal can be improved in the following ítems: 1) when proposing to use VIII Classes confusion is created with the Land Capability Classification that also uses VIII classes, and as was explained was not designed to assign specific uses as is required in this Regulation. The recommendation is to use a different number of classes and not use roman numbers. 2) Land uses, only characterized as given crops, and not as land utilization types, do not have enough elements to establish the degree of suitability. For example, the requirements for corn, whether it is used with mechanization or not, will have very different requirements, and consequently suitabilities for a given soil; 3) The intention of the Regulations to assign more intensive uses as Horticultural crops in the best lands, and more extensive use in lower classes seems adequate. However, the pertinence of land use is not only a matter of agroecological suitability, but also of socioeconomic aspect as well as the context of agricultural development of each area; therefore each zone will have pertinent land uses that have to be identified previously. The concept of land utilization types seems adequate for this end. 4) The factors mentioned in the Regulations for the Classification of Vocation, must be integrated, weighed and valued in order to assure a more objective and consistant classification.; 5) Consequently, in this proposal for the use of Vocation, there has to be a selection of the most suitable uses, that in a short term, can be best harmonized in the region under study, with the other socioeconomic, and infrastructural conditions presently available.

In order to operationalize the proposed concept, Table 2 shows an example of a Decision Table.

Table 2. Example of analysis of Vocation for a land unit with six Land Utilization Types (LUT).

LUT	Suitability	Plan	Infrastructure	Services	Markets	Inputs	Resutls	Vocation
	25	25	25	10	10	5	100	
Htb	1	1	1	1	1	0,5	97,5	High
Ftb	1	0,5	1	1	1	0,5	85	High
Cme	0,5	0,5	1	1	1	1	75	Moderate
Pla	0,5	0	0,5	0,5	0,5	0,5	37,5	Low
Gsi	0	0	0	0,5	0,5	1	15	No Vocation
Tab	N						0	No Vocation

Table 2, taken from a previous proposal (Comerma *et al.* 2005), shows an example applied to a land unit, whose Land Capability Class, only as a reference, is Class II. On the other hand, according to present land uses and some others uses that the Government priorizes, six types of LUT have been preselected: Low tropic vegetables under irrigation, –Htb- (tomatoes and peppers), Low tropic Fruits-Ftb-(guava, citrus); mechanized and fertilized cereals-Cme- (corn and sorghum), Forest Plantations for Wood –Pla-; semi-intensive livestock- Gsi- (double purpose), and Flue cured Tobacco-Tab-..

Table 2 shows the different variables used with different weights as: Suitability according to FAO 25%; Importance of the Government Plan in the region 25%,; Existing infrastructures as roads and irrigation facilities, considering the difficulties for its establishment 25%; Services as centers of storage, processing, and technical assistance 10%; Markets or population with demands of fresh products, 10%, and inputs like fertilizers, seeds, mechanization and agrochemicals 10%. Each variable in that area and for each use is classified as high with a value of 1; moderate as 0.5 and low as 0. In the case of suitability if not suitable will classify as N. These variables can be complemented with others and the weight can also vary according to the region. The final result is on a 100% basis, and it can be classified as high Vocation if the final value is between 80 and 100%, moderate between 40 and 80%, low between 20 and 40% and without Vocation lower than 20%.

Conclusion

Land Capability plays an important role in the qualification of the limitations and establishing the quality of the agricultural lands of a region and/or a country, but does not have sufficient specificity to value which particular uses could be recommended for a given development Project. To fill that gap, the criteria used by the schemes of land evaluation of FAO, establishing the agroecological and socioeconomic suitability of given land utilization types, are considered very adequate as they furnish a menu of options for each land unit, with their different degrees of suitability. But, if there is a need to determine which of these uses is the most appropriate at a given moment in that region, like the one suggested by the Vocation proposed in the new Law in Venezuela, then other factors like the political priority, infrastructures, services, markets and the availability of inputs required for its productions among others should be considered. A simple methodology is proposed including these factors and weighing values to obtain more precise and consistent results.

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A case study in South-east China of operational pedology as a contribution to a project linking research and training

Laurent Bock, **Gilles Colinet** and Daniel Lacroix

Laboratory of Geopedology, Gembloux Agro-Bio Tech, University of Liege, Belgium, Email geopedologie@ulg.ac.be

Abstract
As a contribution to a European Union project aiming to reduce soil loss in the Upper Yangtze catchment, a full geological, geomorphological and eco/agropedological detailed survey has been carried out in order to appraise firstly the biophysical characteristics of a catchment selected to test modified or novel agricultural techniques and secondly its representativeness of the general mountainous context. Soil samples and topsoil composite samples have been selected from augerings, pits or plots for different analytical menus including mineralogical, physical and chemical characteristics. It was noted that if soil erosion is high and soils are mainly colluvial in nature, some red soils trapped in paleokarstic context are the result of previous weathering periods, thereby limiting the possibility of extrapolating field experiments to other parts of the catchment but also to other red soil areas of Southern China. The basis of a soil information system was launched through a map and its table-legend displaying the characteristics or values of the main unit discriminating criteria. This contribution also offers an opportunity to make Chinese colleagues and practitioners aware of an operational methodology and its associated technologies (field techniques, DGPS, remote sensing, soil laboratory analysis, GIS).

Key words
Soil fertility assessment, local soil database, soil erosion, paleo-features, WRB qualification,

Introduction
This presentation summarizes our contribution to a European Union funded project (1998-2002) entitled: “Improving the productivity and sustainability of crop systems on fragile slopes in the highlands of South China and Thailand”. Our specific objective was to conduct a full survey of the biophysical context to appraise its internal diversity/variability and its external representativeness and to provide the database against which to assess internal change and to ensure the limits of extrapolation. Belgian and Chinese students have been involved and contributed with five Master theses (Vinck 1999; Baudoin 2000; Van Caillie 2000; Baire and Ghuisoland 2001) and one co-supervised PhD (Li 2004).

Material and methods
This study was conducted within the 50 ha Wang Jia Catchment (25°28’32” north, 102°52’50” east), which is located near Kelang village (Kedu Township, Xundian County), 60 km North-north-east of Kunming in Yunnan Province (Southwest China). Altitude ranging between 1,860 and 2,380 m asl, the total elevation difference is 520 m and the mean general slope is 15°. In this region of “Eternal spring”, the mean monthly temperature between 8°C (in January) and 22°C (in June, July and August) and the 1,000 mm rain annual average rainfall characterize a subtropical climate at altitude with the effect of an attenuated monsoon regime (77 % of rains fall between May and September).

According to Jenny’s formulation and facing a lack of information at a relevant scale, the principles of an integrated geomorphopedological and agropedological approach (Bock 1994) have been applied to discern the rock – relief – soil – land cover / land use explanatory relations, soil potentialities and constraints and to assess topsoil fertility versus yields.

In addition to some preliminary work on documents, lithological, geomorphological and land cover/use surveys were carried out by outcrop and landform identification, dip and slope measurements, vegetation / crop observation, (3D) aerial photointerpretation. This work included an assessment of erosion and of soil physical properties, especially water availability for plants. Soils were identified by description of hand augerings down to 120 cm when possible along toposequences and observation of soil pits. Topsoil fertility was assessed in different groups of plots well distributed within the catchment (concept of reference plots or “windows”). Therefore, three sets of samples were collected for different menus of mineralogical, and physico-chemical laboratory analyses.

Results

Main geopedological deductions

With shale, sandstone and dolomitic limestone / dolomite (dolostone), three main lithologies have been identified. A clear influence of lithology and bed strikes on catchment main conformation justifies a subdivision in four main physiographic units i.e. in summit, upper, middle and lower sectors.

Soil stoniness varies from stony on steep slopes and/or positions including sandstone to slightly stony on the catchment floor, soil thickness from 40->120 cm and soil texture from silt loam in shale/sandstone areas to silty clay in some dolomite areas. Moreover the soil colour palette expresses (i) the lithochromic influence of sandstone and shale on the soil colour (yellowish brown), (ii) a reddish shade (2.5YR) in the dolomite environment or, more precisely, in relation to a decarbonated residual product and, (iii) some features of mottling in lower positions.

Therefore, these field observations and the particle size distribution (laser measurement) reveal that soil parent materials could be relatively autochthonous, but are more frequently allogenic and that, from up-stream to down-stream and from subsoil to topsoil, they correspond to an increased mixing of products showing evidence of different deposits.

Main mineralogical deductions

The contribution of the parent rock is clearly shown when the clay mineralogy of a sample of shale or sandstone is considered. The shale is highly micaceous, with subsidiary chlorite, whilst sandstone is more chloritic with subsidiary mica. No kaolinite was detected in this lithological context. It is concluded therefore, that the dominant illite/chlorite assemblage found in the soils is a direct reflection of the influence of the parent material. The illite mineral is likely to be mainly of a muscovitic type and chlorite presents vermiculitic layers even before the onset of weathering. But if the illite content is generally higher than that of chlorite, in certain cases and principally in top horizons, this relation is reversed.

However in dolomitic soils, small amounts of kaolinite and gibbsite occur and are undoubtedly related to pedogenic weathering. Both these minerals require somewhat acid conditions, with depletion of basic cations and, in the case of gibbsite, strong desilication of the system. Therefore, the implication is that the soils are intensively lixiviated and this process would cause the vermiculitisation of chlorite and of mica. The red colour of these soils and the identification of hematite in the bulk samples are consistent with this conclusion and further suggest that this occurs in a warm climate.
Consequently, the dominating presence of chlorite in topsoils suggests a more direct influence of sandstone in the more recent deposits. Therefore, these deposits can cover the reddish material which, trapped in a karstic relief, is probably partly a residual product of dolomite decarbonatation.

Main eco/agropedological deductions

On the most sensitive convex positions, topsoil is acidic (pH H_2O <5.6), low in total organic carbon (TOC <0.6%) and relatively base unsaturated (40-60%). In the most favourable concave positions, topsoil is calcic/carbonated (pH H_2O reaching 8.0), higher in TOC (1.6-2.3%) and base saturated (80-100%); the organic profile is also thicker (1.2-1.5% TOC in subsoil). However, the topsoil C/N ratios with values ranging from 9.0-15.0 suggest that mineralization is optimal or just below optimal on some divide or side positions.

Main physico-chemical and chemical deductions

The CEC results, ranging from 5.3-27.2 $cmol_c$/kg of soil, reflect the main components of the sorption complex, giving an indication of the quality and nature of clay minerals and SOM. Therefore, the best potentialities in terms of the best balance between mineral and organic contents and of the resultant CEC concern the lowest catchment parts (floor and outlet). Upper catchment concave positions on shale and middle catchment sides on dolomite lead to an intermediate diagnosis; the lowest one being for soils on eroded interfluves.

Exchangeable calcium (and magnesium) relates closely to pH results; values > 10 $cmol_c$/kg of soil (and >~3) resulting from carbonate dissolution. Exchangeable potassium content is mainly <0.3 $cmol_c$/kg of soil and compared to the optimum cation balance, exchangeable magnesium ratios are high. Exchangeable acidity being mainly <30% of the CEC, there is no risk of Al toxicity.

Main nutrient availability deductions
From plot fertility assessment (composite samples), if total nitrogen content is greater in concave positions than in other positions and potassium availability is only sufficient in some positions on shale, it appears also that total nitrogen, exchangeable potassium and phosphorus contents are far greater near the village showing the clear impact of fertilization. A plan of pH values confirms perfectly a fertility gradient with low values in upper shale and sandstone soils far from the village and higher values in some dolomitic soils or near the village.

Main typological deductions
According to the World Reference Base for Soil Resources (FAO 2006), soils developed:

(i) on shale and sandstone parent material are Colluvic Regosols (Epi to Endoskeletic, Siltic, Hyper to Orthidystric), also locally Magnesic and Anthric,

(ii) in the vicinity of dolomite outcrops are Luvisols (Siltic, Rhodic) or Thaptoluvic Regosols (Siltic) also locally Skeletic and/or Anthric, Orthieutric to Orthidystric,

(iii) at the catchment outlet near village are namely Gleyic Regosols (Calcaric, Siltic, Anthric).

According to Soil Taxonomy and suggestions made by H. Eswaran, J. Sandor and R. Napoli during the Red Cloud Tour as post-Congress excursion of the 17th International Congress of Soil Science in Bangkok 2002, soils of the second group are Fine-loamy, mixed, hyperthermic Typic Haplustalfs or Rhodustalfs.

Main practical deductions
"Natural" vegetation, as mixed forest, pine trees and bush, is limited to steep slopes with outcrops, stony and/or thin soils. Cultivation on catchment sides (some of them being progressively abandoned at the highest limits), catchment heads, interfluve and shoulders, is characterized by sloping terraces. Cultivation on the catchment floor and outlet is on levelled terraces.

In terms of limiting factors, the diagnosis is as follows: (i) in the worst cases, two or three morphological constraints (outcrops, slope, soil thickness) could be associated with two or three physico-chemical constraints (low pH, organic content and CEC), (ii) for other positions, constraints are mainly morphological and stoniness is only considered in certain positions, (iii) in certain flat positions and concave positions, limiting factors are more locally specific, but could also be morphological (except outcrops) and/or physico-chemical, (iv) but in the lowest flat positions, there are no identified limiting factors.

The highest fresh weights of maize are obtained from the most fertile plots (1.8-2.0 kg/m2/yr) and the lowest from the least fertile plots (0.2-0.6 kg/m2/yr); some compensation factors, such as distance from village for manure inputs and strategies dictated by family specificities, can explain intermediate and contradictory diagnoses.

An assessment, based on the Universal Soil Loss Equation, shows that sheet erosion is very high and above the commonly admitted limit. A quantitative simulation of the effectiveness of anti-erosion practices, carried out on 3 representative slopes, has shown that tree planting and mulching would significantly reduce soil loss, but also that other anti-erosive management options, such as diversion channels, gully stabilisation, grass strips, etc. are still necessary in some places.

Linear erosion is mainly due to runoff concentration in channels dug to evacuate excess water from cultivated fields, but with inappropriate sizing. A second cause of runoff increase and rill formation is due to bare soil compaction along paths. Mass movement and particularly soil collapse can be observed mainly on steep slopes on shale or on residual clayey material.

Conclusion
The soils are essentially colluvial in nature. The upper catchment would be continually subject to mass movement further down slope and any weathering mantle that does form here would be subject to this movement and tend to accumulate in the middle and lower catchment.
However, a red clayey material with some hematite, kaolinite and gibbsite is trapped in a paleokarst attesting previous weathering episodes in warmer climatic conditions and makes us hesitate between a Luvisol (Siltic, Rhodic) and a Thaptoluvic Regosol.

Consequently, the results of the main experiment conducted on this red soil cannot be applied uncritically to soils developed on shale and sandstone, neither to other red soils areas of Southern China.

All the data gained were synthesised in the table-legend of a geomorphopedological map. This legend presents line by line the mapping units and column by column the most discriminating arguments that justify and characterize these units. Fields arguments concern the physiography, lithology, land form, land cover and soil morphology, laboratory arguments correspond to the mineralogical and physico-chemical results of soil pit and composite topsoil samples. Limiting factors are suggested and yield of corncob fresh weight of reference plots ensures a link with (socio-economic) data as gained at a farmer level.

This legend therefore provides for this (relatively) unsurveyed mountainous area a good minimum data set for the main soil characteristics and the topsoil fertility state. The fact that references to a soil pit and/or an augering and/or a soil fertility evaluation plot are given, make this legend a good basis to build a local land information system, initiate a strategy of personalized advice and agro-environmental monitoring and finally, encourage participation in land use planning.

This contribution reaches the specific objectives fixed as a first work package in a more EU ambitious project and also offers an opportunity to make Chinese colleagues and practitioners aware of an operational methodology (Bock 2002) and its associated technologies (field techniques, DGPS, remote sensing, soil laboratory analysis, GIS).

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Nutrient optima-based productivity zonality delineation in citrus orchards of northeast India

A.K. Srivastava[A], Shyam Singh[B] and S.N. Das[C]

[A] National Research Centre for Citrus, Nagpur 440 010, Maharashtra, India, Email aksrivas_2007@yahoo.com
[B] National Research Centre for Citrus, Nagpur 440 010, Maharashtra, India, Email shyamsingh_5@yahoo.co.in
[C] Regional Remote Sensing Centre, Nagpur, Maharahstara, India, Email subratondas@rediffmail.com

Abstract
Spatial variability in soil fertility is important in identifying nutrient constraints vis-à-vis productivity zones to rationalize nutrient use and optimize productivity. Leaf analysis and fruit yield data bank 7 states across northeast India were analysed through a diagnosis and recommendation integrated system (DRIS) to determine leaf nutrient optima and a geographical information system (GIS) was used to develop a spatial variogram of nutrient constraints to delineate major production zones. DRIS interpretation revealed leaf nutrient optima as : 19.7-25.6 N, 0.9-1.0, P, 9.9-19.3 K, 19.7-24.9 Ca, 2.4-4.8 Mg as macronutrients (g/kg), 85-249 Fe, 43-88 Mn, 3-14 Cu and 17-27 Zn as micronutrients (mg/kg) vis-à-vis productivity of 33-56 kg/tree. Superimposing the variograms for nutrient constraints, three major citrus productivity zones were delineated as : zone I (26-27^0 8-25’ 13-43” N latitude; 92^{0}23-59’ 0.82-43”E longitude) without Zn-Mg-P-N constraint, with productivity of 69-104 kg/tree as the best productivity zone followed by zone II (26-27^0 25-26’ 36-51” N latitude; 93^{0}23-58’ 2-21” E longitude) having no Zn-P-N constraint with productivity of 52-68 kg/tree and zone III (26-27^0 6-44’ 20-56” N latitude; 91-92^0 33-57’ 6-17” E longitude) with no Zn-P constraint, having orchard productivity of 23-51 kg/tree.

Key words
Productivity zonality, nutrient optima, citrus, DRIS, GIS

Introduction
It is well recognised that crop behaviour and soils are not uniform within a given orchard (Srivastava *et al*. 2006) and growers have generally responded to such variability by taking appropriate actions such as improving drainage, changing fertilization time, source, etc. Advances in software aided decision support systems (DSS) like DRIS and GIS, have led to usage of newer interpretation tools having much wider application potential (Schumann and Zaman 2005; Zaman and Schumann 2006). Precision citrus farming basically depends on correctness of measurement and understanding of the in available supply of nutrients. This can be summarized in three steps viz., i. assessing variation ii. managing variation, and iii. evaluation. The available technologies enable us to understand variability and give site specific recommendations, the variability can be addressed precisely to enable precision citriculture, a viable management strategy. Efforts were made to identify major promising productivity zones for concentrated development of ‘Khasi’ mandarin orchards in northeast India.

Methods
Orchard setup and soil variability

An extensive survey of 108 ‘Khasi’ mandarin orchards was carried out covering 590 sq.km from 50 georeferenced collection sites locations across 7 states (20^o-22’5’ N latitude and 89^{o}37’-97-30^o E longitude). Soils predominantly belonged to soil orders Entisol (Haplaquent, Ustifluvent, and Udifluvent), Inceptisol (Ustochrept and Haplaquept), Alfisol (Rhodustalf, Paleustalf, Haplustalf, Orchraqualf, and Rhodustalf), and Ultisol (Palehumult, Haplustult, Plinthaqult,and Plinthustult). Mineralogically, these soils were grouped as illitic-kaolinitic mixed. Climate is characterized by annual rainfall of 120-1145 cm (mean 180 cm) with mean summer and mean winter temperatures varying between 24.6^{o}C - 32.8^{o}C (mean 28^{o}C) and 9.9^{o}C - 24.8^{0}C (mean 15^{o}C), respectively. Geology is dominated by sedimentary and metamorphic rocks grading from most ancient to recent.

Sampling and analysis

Six-to-seven month old leaves at second, third or fourth leaf positions from non-fruiting terminals covering 2-10% of trees at a height of 15-1.8 m from the ground were sampled and analysed for macro-(NPKCaMg) and micronutrients (FeMnCuZn). Two interpretation tools (DSS) viz., DRIS (Srivastava and Singh 2008) and GIS (Arc 9.3) were used in delineating citrus productivity zones

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Results

Leaf nutrient optima

Validity of leaf analysis as a diagnostic tool lies in the total concentration of nutrients in leaf that relates with production output of the crop. Leaf macronutrient content (g/kg) showed a large variation, 20.5 – 26.5 N (median 24.7), 0.9 -1.3 P (median 1.1), 11.2 - 21.3 K (median 14.3), 18.2 - 24.2 Ca (median 19.8), and 2.2 – 4.2 Mg (median 3.4). Similarly, the micronutrients (mg/kg) varied as, 133.5 - 281.2 Fe (median 138.9), 51.6 - 100.3 Mn (median 60.2), 5.1 - 22.4 Cu (median 8.5), and 14.5 - 25.6 Zn (median 25.5), respectively. Using this databank, leaf nutrient optima (Table 1) for different nutrients were developed through DRIS-based software.

Table 1. DRIS based leaf nutrient criteria for 'Khasi' mandarin of northeast India

	Indices				
Nutrients	Deficient	Low	Optimum	High	Excess
N (g/kg)	< 16.7	16.7 – 19.6	19.7 –25.6	25.7 – 28.5	> 28.5
P (g/kg)	< 0.6	0.6 – 0.8	0.9 – 1.0	1.1 – 1.3	> 1.3
K (g/kg)	< 5.2	5.2 – 9.8	9.9 – 19.3	19.4 – 24.0	> 24.0
Ca (g/kg)	< 17.2	17.2 – 19.6	19.7 – 24.9	25.0 – 27.5	> 27.5
Mg (g/kg)	< 1.4	1.4 – 23.0	2.4 – 4.8	4.8 – 5.4	> 5.4
Fe (mg/kg)	< 22.6	22.6 – 84.5	84.6 – 249.0	249.1 –331.3	> 331.3
Mn (mg/kg)	< 18.6	18.6 – 41.5	41.6 – 87.6	87.7 – 110.6	> 110.6
Cu (mg/kg)	< 1.8	1.83 – 2.1	2.13 – 14.4	14.5 – 20.6	> 20.6
Zn (mg/kg)	< 11.1	11.1 – 16.2	16.3 – 26.6	26.7 – 31.8	> 31.8
Productivity (kg/tree)	< 19.1	19.1 – 31.5	31.6 – 56.3	56.4 – 68.8	> 68.8

Spatial distribution of nutrient constraints

Leaf nutrient criteria developed for 'Khasi' mandarin using DRIS-based software utilized for development of GIS-based maps nutrient constraints distribution maps (Fig. 1) showed that most of the Khasi mandarin orchards were optimum in N nutrition, low to deficient in P and optimum to high in K. Whereas, Ca and Mg nutrition were mostly severely deficient due to the poor supply of Ca and Mg in soil. On the other hand, Fe content was mostly high to excess. Copper nutrition showed deficiency levels, while Mn was mostly optimum to high with majority being at sub-optimum level.

Delineation of productivity zones

Maps for spatial distribution of nutrient constraints were superimposed, this delineated three most important citrus productivity zones. These are Zone I (26-27^{o} 8-25' 13-43" N latitude; 92^{o}23-59' 0.82-43"E longitude) showing no constraint of Zn-Mg-P-N with productivity of 69-104 kg/tree (areas identified as Navgaon, and Rangpara of Assam state); Zone II (26-27^{o} 25-36' 36-51" N latitude; 93^{o}23-58' 2-21" E longitude) without Zn-P-N constraint displaying productivity of 52-68 kg/tree (areas identified as Golpara of Assam state and Mirik, and Lisa hills of West Bengal state); and Zone III (26-27^{o} 6-44' 20-56" N latitude; 91-92^{o} 33-57' 6-17" E longitude) showing no constraint of Zn-P with productivity of 23-51 kg/tree (areas identified as Shergaon, Dirang, and Tengal Valley in the state of Arunachal Pradesh).

Conclusion

Integrated use of two diverse software-based DSS helped in identifying potential sites for sound land use planning using a systematic citrus development program in order to harness sustainability in quality production without any nutrient mining.

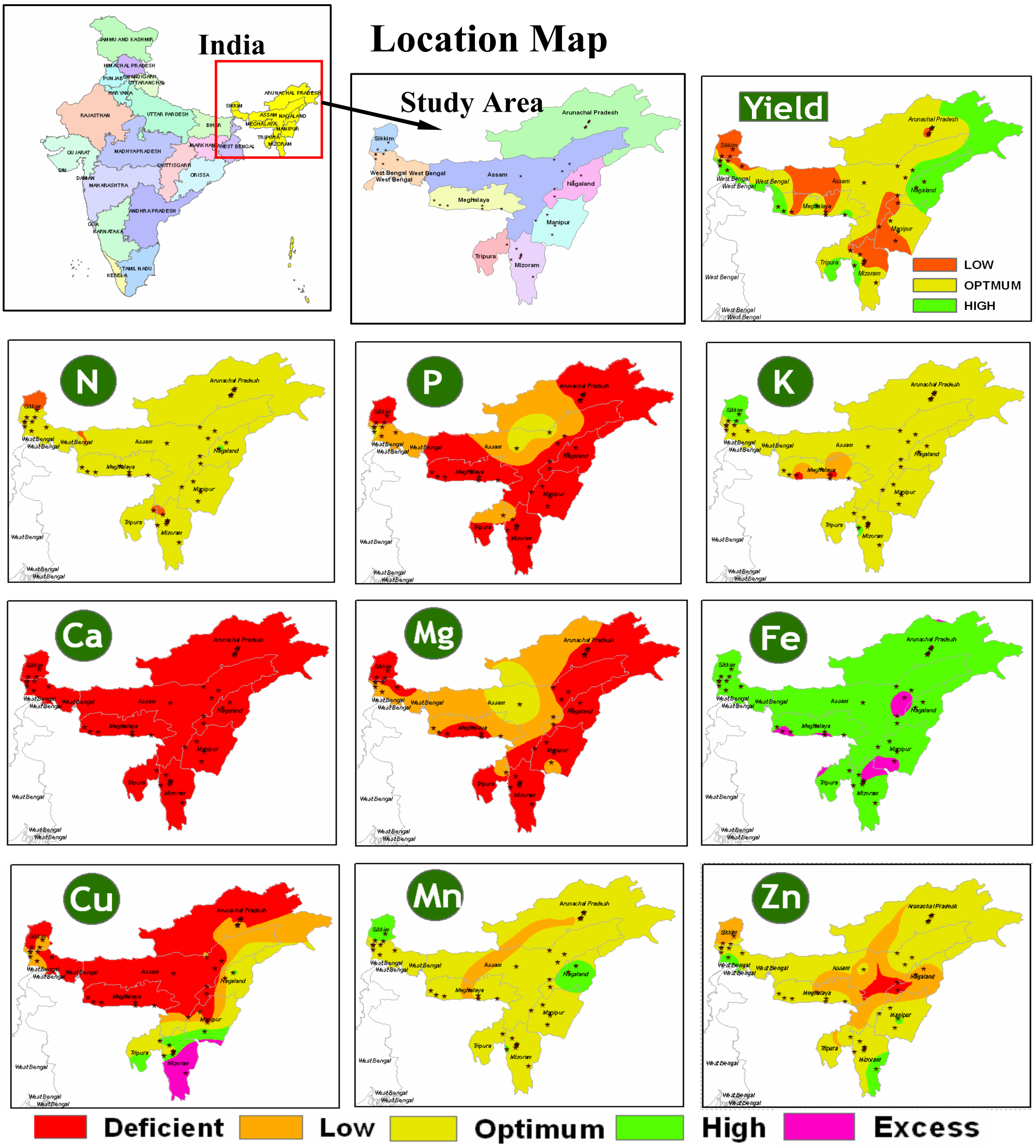

Figure 1: Spatial distribution of different nutrient constraints across seven states of north-east India

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Soil available phosphorus by Mehlich-1, Mehlich-3 and anion exchange resin and its sensitivity to soil clay content

Luciano Colpo Gatiboni[A] , Clovisson Menotti Boeira de Oliveira[A] , Paulo Roberto Ernani[A] Jaime Antonio Almeida[A] and David José Miquelluti[A]

[A]Soil Science an Natural Resources Department, Santa Catarina State University, Lages, SC, Brazil, Email gatiboni@cav.udesc.br, clovissonboeira@yahoo.com.br, a2pre@cav.udesc.br, a2jaa@cav.udesc.br, a2djm@cav.udesc.br

Abstract
Mehlich-1 is the most used chemical method to determine soil available P in Brazil, but its efficacy is affected by variations in clay contents due to the exhaustion of the extractants and readsorption of P by the soil particles. Thus, other methods have been tested in Southern Brazil to replace the Mehlich-1. The objective of this work was to evaluate the ability of Mehlich-1 (M1), Mehlich-3 (M3), and anion exchange resins in strip (AERst) or in sphere (AERsp) forms, to extract P from soils with a wide range of clay contents. Samples were collected from the B horizon of a Brazilian Oxisol were mixed with different amounts of sand in order to get artificial soil samples containing 200, 400 and 600 g/kg of clay, in addition to a pure sand (with no clay) and a pure soil (800 g/kg of clay). Phosphorus rates (0, 100, 200, 400 and 600 mg/kg) were applied to each one of these experimental soils that were subsequently incubated for 1, 30, 90 or 180 days. After each incubation period, available P was quantified by the four methods. All methods, extracted less P as the clay content of the samples increased. The amount of P extracted also decreased with increases on the incubation time. Thus, the evaluation of soil P availability to plants determined by all tested methods need to take into consideration the amount of clay.

Key Words
Phosphorus, soil analysis, availability, Mehlich, resin.

Introduction
Plants take up nutrients only from soil solution. However, soil nutrient availability depends on the relationship between ions in liquid and solid phases since the latter form replace the nutrients in the soil solution as their uptake by plants proceeds. The ability of the solid forms to resist changes in the concentration of a given ion in the solution represents the soil buffer capacity, which is controlled by the binding energy of the nutrient with the soil particles and by its diffusivity to the soil solution. Thus, chemical methods used to estimate nutrient availability from the soil must detect the amounts that can readily go to soil solution. Mehlich-1 is the official method used in Southern Brazil to evaluate soil available P. In this method, labile P is extracted by acid dissolution, which preferentially attacks P pools associated with calcium compounds and, to a less extent with aluminum and iron compounds. This method has the inconvenience of detecting decreasing amounts of P as the content of soil clay increases, due to extractant exhaustion and the readsorption of P on inorganic colloids that takes place in clayey soils following the extraction but before the determination. To overcome this problem, other methods are being evaluated in Southern Brazil to replace Mehlich-1, such as Mehlich-3 and anion exchange resin. The objective of this study was to evaluate the efficacy of Mehlich-1, Mehlich-3, and two forms of anion exchange resin (in strips and in sphere) to extract P from samples of the same soil mixed or not with sand in order to get a wide range of clay contents.

Methods
This work was carried out in the Soil Fertility Laboratory at Santa Catarina State University, in Lages, Southern Brazil. Treatments consisted of a factorial including samples of the same soil containing various amount of clay (0, 200, 400, 600 and 800 g/kg) that received increasing rates of P (0, 100, 200, 400 and 600 mg/kg). Phosphorus was determined in all these samples by four chemical methods [Mehlich-1,M1, Mehlich-3,M3, (Mehlich, 1984) and anion exchange resin in strips (AERst) or in spheres (AERsp) forms, according to Raij et al. 2001)]. The soil sample was collected in the subsurface horizon of an Oxisol. It had 800 g/kg of clay with predominance of kaolinite and iron oxides. To get the variations on clay contents, the natural soil samples were mixed with different amounts of sand, in addition to a pure sand (with no clay) and a pure soil (800 g/kg of clay). The sand used had particle size between 0.5 to 1.0 mm and was previously washed sequentially with HCl 0.1 mol/L and distilled water, several times. The prepared samples were moistened in order to attain 80% of the soil water retained at field capacity and subsequently incubated for

30 days for physical and chemical properties stabilization. Subsequently, $CaCO_3$ was applied to raise the pH-H_2O of each individual sample to 6.0, an a new incubation period of 30 days was performed. At this time, samples were dried, sieved and the P adsorption capacity was determined, through adsorption isotherms adjusted by using the Langmuir model. Then, P rates were applied, as KH_2PO_4, and quadruplicate samples were incubated for 1, 30, 90 and 180 days. During this time, distilled water was added at two weeks interval to keep moisture near 80% of the water retained at field capacity. After each period of incubation, samples were dried at 60 º C, sieved to pass a 2.0 mm sieve, and analyzed for P. It was used a completely randomized design with four replications. Results were submitted to analysis of variance and means were compared by the Bonferroni test. The percentage of recovery of P added was calculated by the following equation:

$$\%Prec = (Pext - Pnill/Padd)*100 \quad (1)$$

where %Prec = P recovery (%); Pext = P extracted from a treatment with P application; Pnill = P extracted from the treatment without P application; Padd = quantity of P applied.

Results

The increase in the clay content of the samples increased the adsorption of P and decreased its recovery by all four chemical methods (Table 1). This is because in sandy soils the number of sites for specific adsorption of phosphates is small, which limits this process and allows P to remain in more available forms. Moreover, raising the clay content increases the adsorption of P and decreases its availability. In fact, all methods tested extracted less P with increases of clay content due mainly to an increase of P sorption. The amount of P extracted by all methods dramatically dropped with increases in the percentage of clay in the samples, showing that these methods are similarly sensitive to variations in soil buffer capacity. For the treatment that did not receive phosphate, all methods showed similar P values regardless of the clay content in the samples (Table 1).

As the rate of P applied increased, the methods also detected higher levels of available P. However, for samples containing the highest clay content (800 g/kg), this occurred only where it was added the highest P rate (600 mg/kg), demonstrating the extremely high sorption capacity of this soil. M1 and AERsp generally extracted more phosphorus than M3 and AERsp, probably due to the acidity of the M1, which causes an aggressive extraction from the colloid surfaces. The higher ability of AERsp to extract P relatively to AERst was probably a consequence of a larger exchange surface area of the former kind of resin. After 24 hours of incubation, the recovery of added phosphorus from the samples with no clay (pure sand) ranged from 80 to 106% (Table 2) while from the pure soil sample (800 g/kg of clay) the P recovered ranged from only 1.1 to 5.8%, which demonstrates the strong effect of clay on P adsorption. In most situations, a slight decrease in P extracted occurred with increases in incubation time probably as the result of increases in the energy of P adsorption by the soil particles. These results show that the time elapsed following the application of phosphate until its extraction from the soil must be considered.

Conclusion

All chemical methods were sensitive to the soil buffer capacity, because they extracted less P as the amount of clay in the samples increased. They also detected a decrease on phosphorus availability with increases in incubation time following P addition. Thus, to correctly interpret P availability to plants soils must be segregated in categories according to clay content regardless of the chemical method used.

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Table 1. Phosphorus determined by Mehlich-1 (M1), by Mehlich-3 (M3), and by two forms of anion exchange resin, in strips (AERst) or in spheres (AERsp), from soil samples with different clay contents as affected by the rate of P applied and by the incubation time following P addition.

Clay (g/kg)	Methods	0 mg P/kg				100 mg P/kg				200 mg P/kg				400 mg P/kg				600 mg P/kg			
		1d	30d	90d	180d	1d	30d	90d	180d	1d	30d	90d	180d	1d	30d	90d	180d	1d	30d	90d	180d
		Available P (mg/kg)																			
0	M1	1,7 a	1,7 a	1,7 a	1,2 a	110,7 a	106,4 a	99,5 a	80,7 a	218,8 a	189,4 a	195,5 a	156,8 a	426,5 a	414,0 a	358,3 a	318,9 b	594,6 a	576,6 a	526,5 a	502,2 a
	M3	1,2 a	1,3 a	0,6 b	1,0 ab	98,1 b	75,9 c	69,1 c	84,1 a	155,1 b	138,2 c	118,5 d	152,7 a	439,5 a	422,5 a	266,9 b	375,8 a	600,8 a	581,8 a	519,1 a	525,1 a
	AERst	0,4 b	0,5 b	0,5 b	0,5 b	78,2 c	75,2 c	72,6 bc	68,1 c	153,2 b	149,8 b	144,4 c	125,9 b	370,5 b	326,2 b	285,8 b	245,3 c	451,3 b	418,3 c	452,0 b	401,7 b
	AERsp	1,1 a	0,3 b	0,4 b	0,3 b	82,0 c	81,1 b	77,2 b	73,6 b	154,7 b	154,6 b	168,8 b	133,3 b	362,2 b	330,3 b	362,1 a	254,6 c	459,2 b	470,8 b	530,4 a	409,9 b
200	M1	1,3 a	1,3 a	1,2 a	1,1 a	14,6 a	14,7 a	13,3 a	9,8 a	28,1 ns	29,9 ns	25,0 ab	25,2 ns	101,3 b	87,1 b	78,7 c	75,2 c	202,8 a	204,5 ab	197,5 ab	145,0 b
	M3	1,3 a	1,2 a	0,7 ab	0,9 ab	10,1 ab	8,3 b	5,1 b	6,7 ab	33,2	27,8	19,4 b	23,5	88,6 b	81,8 b	80,8 c	103,6 b	144,0 b	112,2 c	140,6 c	168,4 b
	AERst	0,6 b	0,4 b	0,5 b	0,3 b	6,7 b	6,3 b	6,0 b	3,9 b	23,3	20,2	31,0 a	20,0	108,9 b	77,9 b	111,5 b	93,0 bc	179,0 ab	161,4 b	155,6 bc	139,9 b
	AERsp	1,4 a	0,6 b	1,3 a	0,9 ab	9,6 ab	8,2 b	6,8 b	8,3 ab	24,4	22,5	20,6 b	26,8	159,1 a	118,5 a	149,2 a	156,1 a	223,7 a	226,9 a	222,9 a	234,7 a
400	M1	1,5 a	1,5 b	1,4 a	1,1 a	7,6 a	6,6 ns	6,3 ns	4,6 ns	16,5 a	12,2 ns	11,2 ns	10,5 ns	49,1 b	44,4 ab	31,8 b	26,7 b	80,9 bc	73,1 bc	72,2 bc	59,4 bc
	M3	0,6 bc	0,5 c	0,3 c	0,3 b	3,0 ab	3,0	1,5	2,4	14,2 ab	9,6	4,7	6,3	36,0 b	27,2 b	23,8 b	26,6 b	38,3 c	54,6 c	53,3 c	41,6 c
	AERst	0,4 c	0,3 c	0,5 bc	0,4 ab	1,7 b	1,7	1,3	1,2	4,3 b	3,8	4,4	2,2	31,0 b	28,8 b	34,3 b	15,3 b	105,3 ab	114,1 b	110,2 b	89,0 ab
	AERsp	1,3 ab	2,8 a	1,1 ab	0,4 ab	6,3 ab	4,3	2,5	2,7	15,1 a	13,8	9,0	9,0	76,3 a	60,3 a	72,7 a	55,6 a	144,7 a	164,6 a	163,3 a	134,9 a
600	M1	1,4 a	1,3 a	1,3 a	1,0 ns	6,5 a	4,8 ns	4,7 ns	3,3 ns	14,1 ns	11,0 ns	10,1 ns	9,8 ns	41,3 a	31,0 ns	28,9 ns	20,9 ns	72,9 b	59,4 ns	51,9 ab	44,9 b
	M3	0,8 ab	0,7 ab	0,5 b	0,6	1,8 ab	1,2	1,0	0,7	4,5	2,9	2,2	2,2	19,0 ab	13,6	5,8	12,0	34,9 b	26,0	21,0 b	26,9 b
	AERst	0,3 b	0,2 b	0,3 b	0,7	1,1 b	0,8	0,8	0,7	4,3	2,4	1,2	2,0	10,7 b	16,2	8,4	6,4	50,6 b	41,4	26,1 b	17,8 b
	AERsp	0,7 ab	0,7 ab	0,6 ab	0,4	4,4 ab	3,5	2,5	2,8	9,3	7,6	5,3	9,4	26,8 ab	17,5	18,7	22,7	124,9 a	62,1	79,9 a	95,9 a
800	M1	1,3 a	1,1 a	1,1 a	2,2 ns	4,4 ns	4,0 ns	3,5 ns	3,4 ns	9,6 ns	6,2 ns	4,4 ns	5,9 ns	24,5 ns	20,4 ns	18,1 ns	11,7 ns	61,5 ns	32,2 ns	25,2 ns	24,4 ns
	M3	0,8 ab	0,7 ab	0,4 b	1,5	0,9	0,7	0,3	0,3	1,9	1,0	0,9	0,7	5,2	4,1	2,7	2,7	16,7	7,0	5,3	6,7
	AERst	0,5 b	0,4 b	0,6 ab	0,5	1,0	0,6	0,7	0,8	2,1	1,9	1,1	1,4	3,4	3,4	2,4	2,5	23,4	7,3	6,3	6,5
	AERsp	0,6 ab	0,3 b	0,8 ab	0,5	3,5	2,5	2,8	2,9	9,0	2,8	5,6	5,5	24,7	21,4	15,7	17,9	59,6	28,5	46,0	41,3

Similar letters in the column, for each clay content, do not differ by the Bonferroni test ($P<0.05$); ns = not significant.

Table 2. Recovery of added phosphorus by Mehlich 1 (M1), by Mehlich 3 (M3), and by anion exchange resin, in strips (AERst) or in spheres (AERsp), samples with different clay contents that received increasing rates of P and were incubated from 1 to 180 days. (Average of all of P doses)

Clay (g/kg)	Method	Incubation time			
		1d	30d	90d	180d
		-------------------- P recovery (%) ---------------------			
0	M1	105.7	99.4	92.8	80.1
	M3	95.8	86.3	70.1	85.0
	AERst	80.5	75.1	72.7	64.6
	AERsp	81.2	79.8	85.0	68.0
200	M1	21.3	20.8	19.0	15.8
	M3	17.6	14.7	14.3	17.7
	AERst	18.6	15.5	18.6	15.0
	AERsp	24.4	21.5	22.5	24.7
400	M1	9.7	8.3	7.3	6.2
	M3	6.1	5.7	4.5	4.6
	AERst	7.1	7.3	7.4	5.1
	AERsp	13.9	12.1	12.7	10.8
600	M1	8.4	6.4	5.8	4.7
	M3	3.3	2.2	1.7	1.9
	AERst	3.4	3.1	1.8	1.2
	AERsp	8.8	5.2	5.5	7.2
800	M1	5.8	3.8	3.1	2.7
	M3	1.1	0.5	0.4	0.0
	AERst	1.5	0.7	0.5	0.5
	AERsp	5.7	3.3	3.9	4.1

P recovery calculated by equation (1)

Suitability of peach in Souma area (Iran), using Almagra model

Ali Asghar Jafarzadeh and Farzin Shahbazi

University of Tabriz, Faculty of Agriculture, Soil Science Department, Iran, Email ajafarzadeh@tabrizu.ac.ir
University of Tabriz, Faculty of Agriculture, Soil Science Department, Iran, Email shahbazi@tabrizu.ac.ir

Abstract
One of the promising areas for the horizontal expansion in west Azerbaijan (Iran) is the Souma area. Peach suitability calculated on the basis of the proposed computer program "MicroLEIS DSS" and presented as a soil suitability map has been integrated with GIS tools. Nine benchmark soil series constituents comprising 35 soil profiles have been selected to represent the variation in soils of the studied area. According to the morphological description, physical and chemical properties and USDA Soil Taxonomy, the soils can be classified as Entisols and Inceptisols. Useful depth, texture, drainage, carbonate, salinity, sodium saturation and profile development were selected as limitation factors for peach development. For perennial crops (peach), soil reference sections are between 0 and 100 cm in depth, or between 0 cm and the limit of useful depth when the latter is between 0 and 100 cm. Following a semi-quantitative procedure and according to the generalization level set up for each soil diagnostic criterion, the area under investigation has been divided into four relative suitability classes. Results showed that texture and drainage are the most important limitation factors in 2266 ha and 66 ha respectively of the study area. Peach garden development can be recommended for 1824 ha of the studied area with special reference to sustainable agriculture achievement.

Key Words
Almagra model, MicroLEIS DSS, suitability, Souma, GIS.

Introduction
The Almagra model constituent of new MicroLEIS DSS frame work has been established for the Mediterranean area (De la Rosa *et al*. 2004). Since the last decade, it has been widely used to evaluate many different areas. The Almagra –Tuxpan developement based on the specific conditions of Nayarit (Lopez Garcia *et al*. 2006) was carried out based on a semi-detailed soil survey, Using the Almagra-Tuxpan model, a software routine was written to evaluate the agricultural aptitude of twelve traditional crops (bean, sorghum, maize, tobacco, Virginia, Barley, chili, tomato, melon, watermelon, jícama, peanut, and cotton), after that, the relative agricultural aptitude was determined for every one of the mapped soils units.
Suitability evaluation for specific crops is the first step in land use planning. For this purpose, soil survey and climate are two main factors which impact on land use type. MicroLEIS DSS as a new method in land suitability evaluation was used in Iran for the semi-arid region (Shahbazi 2008 a). The research dealt with sustainable land suitability evaluation of the Ahar soils, located in East Azerbaijan, Iran, based on the multifunctional evaluation of soil quality, using input data collected in standard soil surveys, and with particular reference to the peculiarities of the Mediterranean region and recalibration and validation tests were applied for the new semi-arid condition. Land use planning in Ahar area using MicroLEIS DSS (Shahbazi *et al*. 2008 b) showed peach gardens were recommended only for 30% of the total area heavy texture being the major limitation factor in this case.
Bioclimatic deficiency and land capability evaluation must be carried out to separate agricultural lands from the marginal land. Some special phenomenon such as climate change can be considered in land capability and bioclimatic deficiency evaluation (Shahbazi *et al*. 2008 c; 2009 b). The evaluation results showed that with climate change, only wheat will be converted from moderate to good land use capability in the study area of Ahar, while none of the crops will change its land capability in the Seville area for future scenarios. Also, it is revealed that climate perturbation effects on rainfed conditions are higher than for irrigated conditions in the area. According to previous research work in the studied area (Shahbazi *et al*. 2009 a; Jafarzadeh *et al*. 2009), 80.49% of the total area was capable of agricultural use and 19.51% must be reforested and not dedicated to agriculture. Soils are Typic Xerofluvents, Typic Calcixerepts with high carbonate percentage and Fluventic Endaquepts with 812ha extension not suitable for agricultural use and which must be reforested, while Typic Calcixerepts, Fluventic Haploxerepts with 3344 ha are mainly high suitable and in some cases excellent or moderately suitable.

Another novel model of land suitability evaluation was built based on computational intelligence (Jiao and Yaolin 2007). A fuzzy neural network (FNN) was constructed by the integration of a fuzzy logic and an artificial neural network (ANN). Genetic algorithm (GA) was employed as the learning algorithm to train the network, and makes the training of the model efficient. This model is a self-learning and self-adaptive system with a rule set revised by training.

Methods

Site and soil information

This study was performed in the Souma area between 44°35' to 44°40' east longitude and 37°50' to 37°55' north latitude, in the North-West of Iran (West Azerbaijan) which is close to Urmieh with different physiographical units of plain, alluvial plain, plateau and hill side. In the area with an approximately 4100 ha extension, slopes and elevation range from 2–10%, and 1200–1400 m above sea level, respectively. Graphical representation using a climate database package (De la Rosa *et al*. 1986) according to climate characteristics of the study area is shown in Figure 1.

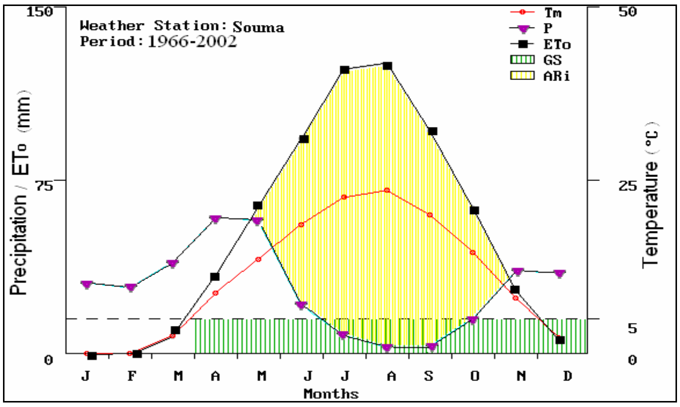

Figure1. Graphical representation of climate information for the Souma area, (Tm) mean temperature (P) mean annual precipitation (ETo) potential evapotranspiration calculated by the Torenthwaite method (GS) Growing season aridity index (ARi).

According to the morphological description, physical and chemical properties and USDA Soil Taxonomy (USDA 2006), the soils can be classified as: Typic Xerofluvents, Typic Calcixerepts, Fluventic Haploxerepts and Fluventic Endaquepts (Figure 2).

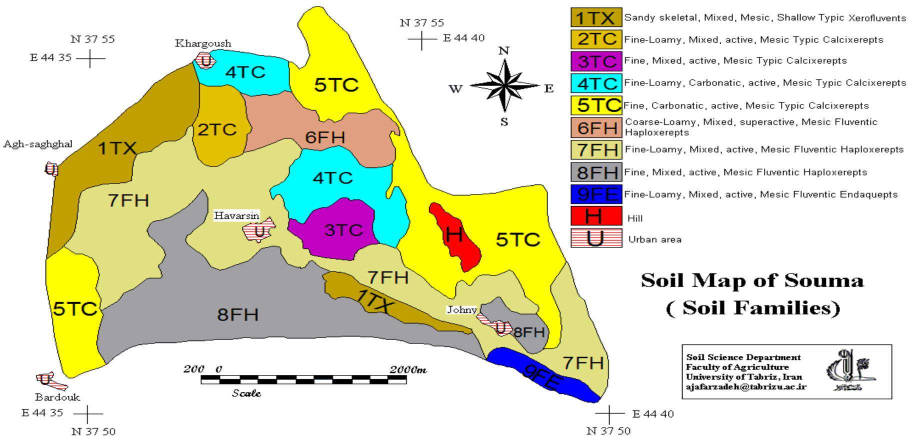

Figure 2. Soil Family Map of the study area

Useful depth, texture, drainage, carbonate, salinity, sodium saturation and profile development were selected as limitation factors for peach development. For perennial crops (peach), the soil section considered is between 0 and 100 cm in depth, or between 0.0 cm and the limit of useful depth when the latter is between 0.0 and 100 cm.

Almagra model

Within the new framework of MicroLEIS, the Almagra model fits the suitability of specific crops of which peach is one. The control or vertical section of soil for measuring texture, carbonates, salinity and sodium character was established by adapting the criteria developed for the differentiation of families and series in the Soil Taxonomy. It refers to between 0.0 and 100 cm in depth, or between 25 cm. and the limit of useful

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depth when the latter is between 0.0 and 100 cm, or in some part of the soil is within the useful depth for perennial crops e.g. peach (*Prunus Persica*). Five suitability classes optimum, highly, moderately, marginally and no suitability are represented an S1, S2, S3, S4 and S5 respectively. Once the land unit data have been entered, Almagra gives an on-screen evaluation based on the criterion of the maximum limitation and verification of the degree of a single variable is sufficient to classify the soil in the corresponding category. Suitability classes will be identified with attention to the land characteristics.

GIS spatialization the results

The soil survey maps, in a geographical database format correspond to polygon multi-factor maps, they represent the main source of basic data to expand land evaluation results in geographic areas. Also, additional basic information can be extracted from other soil survey related maps, such as the land use maps. The conversion of the different basic maps to the same geographical projection is a prerequisite to continue the spatial analysis procedure. Previously, several semi-automatic spatial studies were developed using several basic information maps (Bonneau 2002). To extract information from original maps to be used in the evaluation models, the original polygon maps (multi-factor covers) were converted into grid maps (single factor covers). This task was done automatically by ArcView which takes into account the needed input variables to apply to the particular evaluation using the Almagra model.

Results

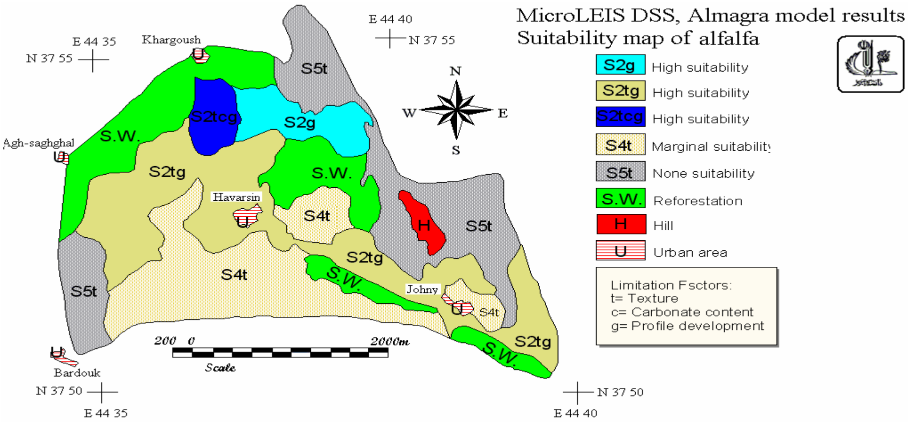
According to soil analysis data and applying the Almagra model (Table 1), soil texture, carbonate calcium, profile development and drainage are recognized as limitation factors for peach garden development. Limitation for the nine benchmark soil profiles are sand or gravel and permeable lime for 1319 ha and 2834 ha, respectively. The results showed that only 35.66% of the total area is classified as highly suitable land (S2) for peach trees with soil texture, profile development and calcium carbonate limitation factors. Only 22.1% of the total area was distinguished as a not suitable because of soil texture limitations (Figure 3)

Table 1. Summary of soil analysis data (0 – 100 cm) and suitability classification

Soil units	Ext. area (ha)	Lowest section of soil	depth (cm)	Stoniness (%)	Texture	Drainage	calcium Carbonate (%)	EC (dS/m)	ESP	Suitability classes
1	403	S/G*	100	55	SL	Well	1	0.27	1	##
2	126	P.L.**	130	18	L	Well	18	0.32	0.96	S2tcg
3	125	P.L.**	100	14	C	Moderate	27	0.25	1.2	S4t
4	343	P.L.**	120	10	CL	Well	45	0.28	1	##
5	916	S/G*	120	35	C	Well	35	0.26	0.94	S5t
6	223	P.L.**	100	2	L	Well	3	0.39	1	S2g
7	1132	P.L.**	120	5	CL	Well	3	0.4	1.11	S2tg
8	822	P.L.**	100	2	C	Moderate	6	0.27	1	S4t#
9	66	P.L.**	100	4	L	poor	5	0.38	0.91	##

Conclusion

The area covered with the “Fine, carbonatic, active, mesic, Typic Calcixerepts” soil family comprising total of 916 ha is the most unsuitable land for peach development which mainly occurs in the north-east of the study area. Besides 812 ha on marginal agricultural land, 947 ha of the total area, because of soil limitation factors is classified as marginally suitabile. Soils in the north of the Havarsin and Johny natural region are classified as highly suitable for peach development. To favour sustainable agricultural development of peach gardens it is recommended they be located in the highly suitable area which is revealed in the suitability map (Figure 3).



Figurer 3. Suitability map for peach garden in the Souma area

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The assessment of land suitability in the implementation of homogeneous stands of Eucalyptus: prospects for a forest sustainability in Brazil

Helena Saraiva Koenow Pinheiro and Lúcia Helena Cunha dos Anjos

Department of Soil Science, UFRRJ. E-mail: lanjos@ufrrj.br

Abstract
The demand for forest products is growing, and in this context commercial plantations of eucalyptus have been planted due to multiple uses of the wood. Areas intended for the establish most of new populations of the genus, when judged against the test systems commonly used in Brazil, are classified as inefficient. The systems are based primarily for the characteristics of agricultural crops, ignoring eucalyptus tolerance to some factors, such as low soil fertility, and the high level of technology employed in commercial plantations. This paper is a critical analysis of some systems of land suitability and their application to the implementation of homogeneous forests of eucalyptus.
The systems of land suitability evaluation, seek to define the quality of sites and make possible recommendations for the improvement of limiting factors for the development of plantations. The attributes with direct influence on the productivity of eucalyptus, can be divided into five factors: effective depth, drainage, soil fertility, erosion susceptibility and impediments to mechanization. Due to the current situation of forestry in Brazil, it is justifiable to use a system compatible with limitations that are less restrictive and inclusion of other factors relevant to the planting of eucalyptus.

Key words
Ability to use, forest planning, eucalyptus trees, diagnostic attributes.

Introduction
Tropical ecosystems have suffered great pressure due to the demand of the population for their forest products, construction and agricultural expansion. The establishment of forest stands, without planning their technical efficiency is the target of several criticisms, coupled with lack of reliable information, showing the need to research and organize the sector. This picture becomes more complicated when we cover the entire Brazilian territory, due to the size, heterogeneity of environmental factors and different stages of regional development.
Forestry implies the adoption of management practices and the division of strategic nature reserves and conservation areas, to ensure the survival of flora, fauna, protection of springs and other natural resources. The planning of land use should be a priority when trying to mitigate the actions of degradation and deforestation, since the use of natural resources is intense. Even with the development of forestry and consolidation of the Brazilian forest, land evaluation for forestry is still deficient, mainly due to a lack of precise information the physical environment and behavior of the species planted.
Brazil has been gaining attention from international investors because of the high forest productivity not only due to promising financial returns, but to present an inverse relationship with the typical volatility of capital markets (Abraf 2008). Another consideration for the return on forestry activities is that they can be preserved, renewed or extended in quantities needed for commercial exploitation, as a variable stock, similar to capital (Golfari 1980). Planted forests have made a great contribution to the area of the Brazilian forest, mainly of with genus Eucalyptus (SBS 2007). The successful expansion of homogeneous stands of this kind is due to the adaptability of the crop to various environmental conditions, diversity of uses and a large number of species. Probable the exotic species have natural resistance to insects and microorganisms and may have a higher production compared to the native plants of the region (Ferreira 1989). This paper aims to review the systems of assessment of the suitability of the land and its use in the implementation of homogeneous plantations of eucalyptus in Brazil.

Material and methods
Eucalyptus
Eucalyptus comes originally from the forests of the Australian and Indonesian archipelago. In general they are adapted to different vegetation types, soil conditions and climate are mostly typical forest trees reaching high 30 to 50 metres tall, and open forests with smaller trees between 10 and 25 metres high. they are dicots,

belonging to the family of Myrtacea with simple opposite or alternate leaves, depending on the species and age of the branch with inflorescence forming a calyptra (Souza *et al.* 2008), they have a complex taxonomy to classify the level and number of species, with differences between authors, due to the relative ease in performing crosses between species of the same region.
The characteristics relevant to forestry, the most common eucalypt species include: tolerance to soils with relatively poor nutrients availability and high concentrations of aluminum, development in conditions of high luminosity, varieties through genetic inter-and intra-specific crosses for different climatic conditions, high natural variability of the species in the zone of occurrence. The development potential of a species in a given location will depend on the quality of the site, the characteristics of the species, quality and origin of the seedlings, as well as the techniques of soil preparation, spacing and management of the stand.

Ability of land
Implementation of eucalyptus usually demands large areas, which mostly entails some limitation on the quality of the site. Analyzing the production of various areas of southeastern Brazil, Barros (1990) correlated the presence of large clumps of eucalyptus with the biological production being dependent on water availability and soil fertility. Soil surveys, used as a basis for information systems assessment of the suitability of the land, are an important tool to indicate the physical limits, climatic variables and summarize the main environmental characteristics and formation of the landscape and changes resulting from land use. The systems of land use assesment, presented below, will be used as a basis for the considerations of this study.
The evaluation system of agricultural capability of land - SAAAT (Ramalho Filho and Beek 1995), is the third edition and has undergone several changes in its classification system. This method of interpretation of soil is carried out based on the results of surveys with soil-physical-environmental (soil, topography, climate and vegetation).
The classification system of agro-ecological suitability of land for the eastern region of Paraguay - SCAAT (Oliveira & Sosa 1995) maintains that all land use by humans, causes an environmental imbalance of variable intensity depending on how it is done. The estimate of the magnitude of the considered parameters normally obtained in soil surveys, is based on variables with high synthesis and predictive capacity, together with climatic and environmental information.
The capacity use system was originally developed in the United States (Klingebiel & Montgomery 1961 adapted by Lepsch *et al.* 1983) in order to group soil characteristics and properties common to homogeneous classes of land, to predict the maximum capacity of a land use without risk of soil degradation, mainly by erosion.

Results and discussion
The delineation of work units with similar environmental conditions in accordance with the quality of the area where you plan to deploy a given culture and the needs for satisfactory production, is defined by the ability of the land based on the interpretation of the limiting factors and level at which they express themselves on site. From the definition of the capacity of use of each site, the recommended practices of soil amendment, management of settlement and appropriate rotation cycle becomes more easily understood and enforceable. Table 1 shows a suggestion for the organization of parameters to assess the usability of a site must be based on the type of influence of the active factor and the possibility of improving this. Among the most influential factors in the productivity of eucalyptus, the inherent soil characteristics that were considered most important a: effective depth, fertility of soil, drainage, erosion susceptibility and impediments to mechanization.

Table 1. Limiting factors and organization of land suitability for stands of eucalyptus.

Limiting factors	Effective depth	Drainage (O_2, H_2O)	Fertility of soil	Erosion susceptibility	Impediments to mechanization
Level of restriction	Null, Slight, Moderate, Severe, Very severe				
Classification for forestry use with eucalyptus	Good, Regulate, Restrict, Inappropriate				
Considerations on the use of land	Necessity of investment and restriction to use →→→→→→→→→→→→→→→→→→→→→→→→→→→→→→→+ +←←←←←←←←←←←←←←←←←←←←←←←←←←←←←←← Quality and Intensity of use				

The systems of land suitability, when applied to areas intended for forest production, have a different diagnoses based on specific criteria and priority for each land use. In analyzing may a forest area under these systems, some aspects are debatable. The system capacity use (Lepsch 1983), despite the ease of understanding and classification by physical attributes, little affected by human intervention, the classification of potential using a conservation focus at the expense of important variables, to achieve satisfactory productivity such as soil fertility. Silvicultural practices, management of settlement and land are not considered viable to improve the restrictions, in some systems. The S.C.A.A.T. (Oliveira & Sosa 1995) considers land use inherent risk of impact due to the proposed management, and this excludes the use of areas with strong slope for corrugated silvicultural use, even with advanced management (C level) by not showing satisfactory performance of the machines. Decomposition of the factors, instead of grouping the variables according to the nature of the restriction on productivity make it difficult to assess specific limiting factors or recommend practices for improvement. Development based on the characteristics of a region may be used to classify the land to be restricted to agriculture or as suitable for use exclusively as pastoral land or forestry.

Most systems for assessing land suitability used primarily the establishment of agricultural crops, so the classification methodology reflects this direction. The methodology proposed in S.A.A.A.T. is no different, it refers to annual crops grown successively in short cycles, dividing suitable land into subgroups according to the level of crop management, widening the areas suitable for forestry, and recognizing only the intermediate technological level (level B) and viability of improvement. The application of this system becomes ineffective when the reason for investment in forestry, especially with regard to the level of fertility and topographic conditions (Gonçalves 1988) that directly relate to machinery, erosion, soil depth and drainage conditions. The Evaluation System of Agricultural Capability of Lands, recommended by Ramalho Filho & Beek (1995), was initially for the cultivation of grains according to the needs of the time it was developed in the 70s. The areas classified in this system as suitable for forestry purposes, assume a middle management level (level B) and have limitations that make it impractical for use with annual crops. The point of greatest restriction on the use of silviculture, in this system is the lack of oxygen, followed by water scarcity, impediments to mechanization, fertility, and finally susceptibility to erosion. Incompatibility in adopting this system for forest production occurs in the first instance in the area evaluated by SAAAT Most of the production forests of the country are large plantations in areas with high capital investment, which together with research and technical knowledge, in genetic improvement, technology exploitation and silvicultural practices in the conduct of the stands, set the industry at a high technological level, so level C and not B. The redefinition of indicators of the capacity of land for the cultivation of eucalyptus is justified because of the particular behavior shown by species of the genus in relation to the characteristics of the environment, and economic importance to the forestry sector in the country.

Conclusions

Although there are several methods for assessing the suitability of the land, to date there is no recommended technique and technology for plantations of eucalyptus. The use of factors of production parameters and relevant to management systems of high technology, can provide a better assessment of the suitability of land for plantations. Research to provide data on the behavior of the species, according to the intensity of land use throughout the production cycle in conjunction with the use of appropriate methodology for understanding the integration of physiographic and edaphic factors and the effect on the productivity of stands eucalyptus, are necessary to substantiate the proposed considerations.

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